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UNITED STATES DEPARTMENT OF AGRICULTURE

# MEAT DEHYDRATION

## A Report of Research Work for its Commercial Development

*Prepared under the Direction of the Committee on Dehydration of Meat, Agricultural Research Administration, United States Department of Agriculture*

## CONTENTS


| | Page |
|---|---|
| The problem and scope of work | 1 |
| Meat, equipment, and processing | 2 |
| Packaging | 15 |
| Compressibility | 18 |
| Control of bacteria and molds | 20 |
| Chemical composition and changes | 22 |
| Nutritive value of protein and fat | 26 |
| Vitamin and mineral content | 28 |
| Rehydration | 30 |
| Palatability | 32 |
| Further comparison of processes | 38 |
| Specifications for commercial production | 42 |
| Summary and conclusions | 44 |


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## *Committee on Dehydration of Meat*

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Acknowledgment is made also to the many other collaborators and their assistants who made contributions to the investigations.

## THE PROBLEM AND SCOPE OF WORK

Early in 1942, soon after the United States entered World War II, the Department of Agriculture recognized the possibilities offered by the successful dehydration of meat. The world food situation already was becoming acute. Clearly the development of practical methods for producing dehydrated meat of satisfactory quality would lead to substantial savings in vital shipping space and weight. The possible need to employ air transportation for food urgently needed, both during the war and afterward, received consideration also.

From the standpoint of long-distance shipment, fresh meat has the disadvantages of being bulky and perishable. Frozen and cured meats likewise, although not perishable, occupy a relatively large space, and besides there is the problem, together with expense, of maintaining the former in a frozen state. Canned meats normally keep well but they, too, are bulky.

Under the circumstances, the problem of successfully dehydrating meat called for intensive research to be conducted with all possible dispatch. Investigators of the Department's newly organized Agricultural Research Administration, which comprises the principal research bureaus, undertook the work as an emergency project. A committee of scientists, experienced in the planning and techniques of research and familiar with practices of the food trades, was appointed. Agencies represented were the Bureaus of Agricultural and Industrial Chemistry, Animal Industry, Dairy Industry, Human Nutrition and Home Economics, and also, through cooperative arrangements, the University of Chicago. Representatives of the meat industry and officials of the armed services and lend-lease agencies were brought into consultation. Besides the planning of research, a further purpose was to determine, in cooperation with the Food Distribution Administration and the American Meat Institute, specifications for acceptable dehydrated meat.

A prompt survey of existing knowledge showed that though the dehydration of fruits, vegetables, milk, and certain other products—including some products other than food—had been investigated, practically no work had been done on the dehydration of meat. Consequently there had been little commercial development in the meat-dehydration field except for the preparation of a few cured products—drief beef, for example—in which partial drying was combined with salting, smoking, or other curing operations.

The problem confronting research workers consisted in determining the applicability, to meat, of known methods of drying other foods and the possible development of new processes. The effects of dehydrating methods on the wholesomeness, palatability, keeping quality, and nutritive value of the product were other essential elements of the study. Still other necessary considerations were packaging and storage.

In the early stages, the investigations were largely exploratory, in search of promising leads on such points as the best grade and fatness of animal; the best method of precooking; the best size of meat particle for dehydration; and the best temperatures for the different methods of dehydration selected for study.

The Department of Agriculture's Research Center at Beltsville, Md., was selected as the most suitable place for conducting the studies, except that a few phases, subsequently described, were carried on at the University of Chicago. The research work provided information on principles and practices helpful in developing commercial supplies of dehydrated meat quickly and in quantities adequate to wartime needs. This report is a condensed description of the investigations and their principal results.

## MEAT, EQUIPMENT, AND PROCESSING

The meats selected for study included beef, pork, mutton, and lamb. In general, the beef used for dehydration in the work at Beltsville was of Commercial grade and consisted of chuck, rib, plate, loin, round, shank, rump, and flank. Most of the pork was graded Choice. It was used in the proportions that result from the usual method of cutting up a carcass and included ham, loin, picnic shoulder, shoulder butt, and lean trimmings. The mutton was obtained from 3- to 4-year-old ewes and wethers, the majority of Commercial grade. The lamb meat was from animals approximately 10 months of age, most of this meat also being of Commercial grade. The chemical composition of the raw material varied widely, depending in part on the fat content, which in turn was influenced by the closeness of trimming.

The steps involved in processing the boned and trimmed meat were grinding, cooking before or after grinding, and dehydration proper. The grinder was a motor-driven machine of the usual type equipped with a set of plates having holes of different diameters, thus providing means of controlling the size of meat particle. Precooking equipment consisted of open steam-jacketed kettles, a double-drum drier of a type formerly used extensively in the dehydration of milk, a steam-pressure cooker, or retort, and a vacuum rotary machine designated in this report as "vacuum rotary dehydrator A," in which both the precooking and the dehydrating were done. Five general types of dehydrators were used: Vacuum rotary, plate vacuum, cabinet (or tray), air rotary, and air flotation.

The various processes of dehydration studied were classified, according to method of precooking and subsequent drying, under seven general headings, as follows: Vacuum rotary, plate vacuum, kettle cabinet, drum cabinet, retort cabinet, kettle air rotary, and drum air flotation. An eighth method, the freezing cabinet, involved the attempted dehydration of raw meat.

### Vacuum Rotary Method

The vacuum rotary method had been used for drying many other materials. Moreover, one of the large meat-packing firms in the United States had tried it experimentally for the dehydration of beef, but the results had not been satisfactory. Among the apparent advantages of this method were the rather wide availability of the equipment and the simplicity of its operation, together with the fact that both precooking and drying could be done in the single machine.

One of the machines, vacuum rotary dehydrator A (fig. 1), obtained for experimental use consisted essentially of a horizontal cylinder 4 feet long and 2 feet in diameter, with a capacity of 300 pounds of raw meat. It was equipped with a steam jacket covering the horizontal surface of the cylinder and with paddles inside

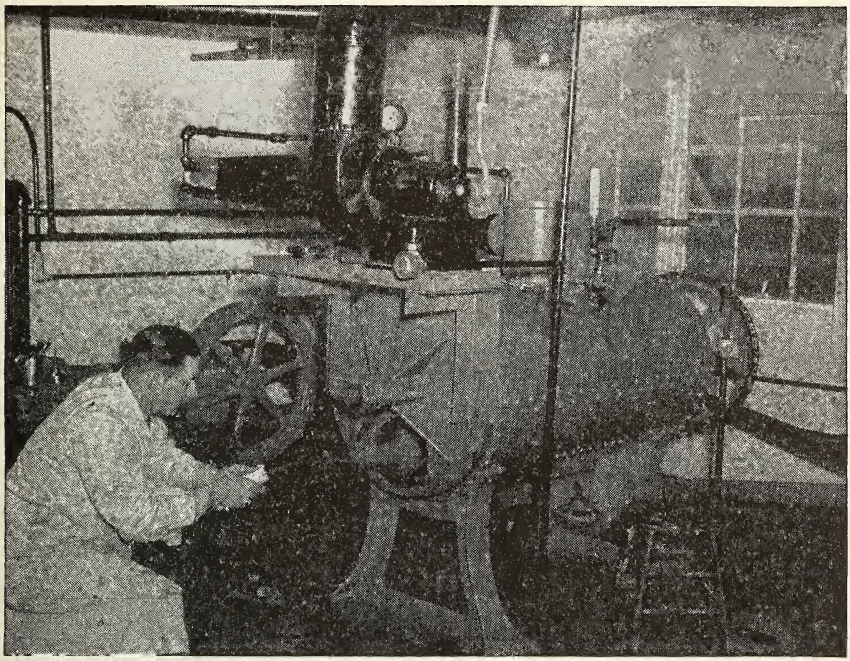

FIGURE 1.—Vacuum rotary dehydrator A. One of the steps in cleaning the machine is being carried out. The auxiliary attachment at the top center is a combination heater and blower for forcing heated air into the drier during the precooking stage of the operation.

to agitate the meat during the drying operation. A heater-and-blower attachment was added, which blew heated air into the machine through the feeding vent at the top. During the cooking period, prior to the vacuum drying, this heater-and-blower attachment was employed to force from the machine the free moisture that came from the meat, thus greatly reducing the time required for the processing operation.

**It is recommended that exposed portions of this and other dehydrators through which steam passes be properly insulated not only to save heat but also for the safety of the operator.**

For precooked pork and beef containing 4 to 18 percent of fat on a raw basis, the time required under vacuum to reduce the meat to 10-percent moisture content—the maximum allowed under Department specifications for commercial production—was 3.5 to 4 hours, when precooking was done at 212° F. for 70 minutes. When the meat was precooked at 165° for 70 minutes, the vacuum-drying period was of 4.5 to 5 hours' duration. In this machine, fat meat dried as rapidly as did lean meat, and large meat particles of medium or high fat content dried as rapidly as did small particles.

The largest load that caused no undue mechanical strain on the drier resulted in the greatest yield per unit of time.

The greatest amount of heat (derived from 5 to 30 pounds of steam pressure) was used during the initial stage of vacuum drying. The large amount of moisture evaporating at this time tended to reduce the temperature and also prevented scorching of the meat. When the meat temperature rose to 135° F., the steam pressure was reduced to 5 pounds or lower to prevent heating the meat higher than 155° at the end of the drying period.

The most practicable drying conditions were as follows: 200 to 300 pounds of raw meat was ground through the plate having 0.25-inch holes and was placed in the machine. The shaft to which the agitators were attached was set to operate at three revolutions per minute. Since there were four agitators or paddles, one passed a given point on the inside of the machine every five seconds. Fifteen to 30 pounds of steam was used in the jacket; the heater and blower removed the free moisture. After 70 minutes the machine was capped and the meat dried under a 28- to 29-inch[1] vacuum, with 5 to 15 pounds of steam pressure in the jacket. When the meat temperature reached 135°, the steam pressure in the jacket was reduced so that the drying was completed without the meat temperature exceeding 155°.

Two other machines of the vacuum rotary type, designated B and C, were used in the research at Beltsville. Basically the construction of dehydrator B was similar to that of A. However, it was equipped with an agitator internally heated by steam, and the capacity of the dehydrator was about 40 pounds of raw meat.

Vacuum rotary drier C differed essentially from the other vacuum rotary driers in its method of agitation during the vacuum-drying period. Instead of being equipped with internal agitators, the entire steam-jacketed vacuum-drying chamber rotated slowly. It was hexagonal in shape, and during rotation the meat tumbled constantly from one flat surface to the next. This machine, too, was of laboratory size and small capacity.

The scope of the studies on driers B and C was limited owing to the fact that they became available late in the course of the investigations. Such factors as temperature of the steam jacket, degree of vacuum, level of meat in the drying chamber, and particle size of the raw meat were studied. As an example of results, the most promising combination of conditions for dehydrator C seemed to be the cooking of meat under an 18-inch vacuum at 165° F. for 30 minutes, then drying at 29-inch vacuum with adequate steam in the jacket (4 pounds) to keep the meat heated, during the wet stage, to a maximum of 135°. As drying progressed, the steam was decreased to prevent the meat temperature from rising higher than 155°. A particle size of 1.1 inches was suitable.

### *Résumé of Vacuum Rotary Method*

The vacuum rotary method involves minimum contact of the meat with oxygen of the air during at least the later stages of drying, when, it is believed, there is the greatest

[1] Signifies height of mercury column used to measure degree of vacuum.

danger from that source. In the equipment with which most of the work was conducted (vacuum rotary dehydrator A), full use is made of heat and moving air during the early stage, when the moisture content is high and damage from overheating is unlikely. According to various criteria, dehydrated pork of good quality is produced with this equipment.

## Plate Vacuum Method

Another type of machine that has long been used for drying various products and substances, practically in the absence of air, is known as the plate vacuum dehydrator. One of these machines, of laboratory size, was available at the Beltsville Research Center and some study of its adaptability to meat drying was considered desirable. Of sturdy construction to permit a high degree of vacuum (exceeding 29 inches), this dehydrator was about 25 inches wide, 17 inches high, and 30 inches from front to back. It was equipped with four hollow plates or shelves so connected with service lines that refrigerating brine (at 5° to 10° F.), water at a wide range of temperature, or steam could be run through them.

Three series of experiments were carried out to dehydrate pork in the plate vacuum drier. In each series the meat was dehydrated with and without prior cooking and with and without prior grinding. In the first series, after the preliminary treatment with respect to cooking and grinding, all samples were frozen and dried at 12° to 18° F., under 28- to 29-inch vacuum; in the second series all samples were heated at 140° to 180° and dried under vacuum; and in the last series all were alternately frozen and heated while drying under vacuum. On the average, series 1 and 3 required more than 40 and 25 hours, respectively, whereas series 2 required only 4 to 6 hours to dry to 10-percent moisture content. In each series cooked meat dried more quickly than did raw meat, and ground meat more quickly than unground meat.

### *Résumé of Plate Vacuum Method*

At best the capacity of this type of dehydrator is limited. The advantages are that drying can be carried out at low temperatures and in the absence of air; the meat particles largely retain their form; and if desired, evaporation can be continued until the meat reaches a very low moisture content. A further and important use of the plate vacuum dehydrator is as a secondary machine for reducing the moisture content of meat below that attained in an air dehydrator.

## Kettle Cabinet Method

The kettle cabinet method is a combination of preliminary cooking in a kettle and dehydration in a drying cabinet. Open, steam-jacketed kettles are standard equipment in meat-packing plants, and the cabinet dehydrator, in which the substances to be dried are placed on trays and exposed to moving heated air, is perhaps

the most widely known type.[2] Figure 2 shows one of the cabinet machines used in the investigations. The conditions in a cabinet drier, sometimes called a tray drier, may be varied yet controlled. Hence, it was logical that the kettle cabinet process should be studied.

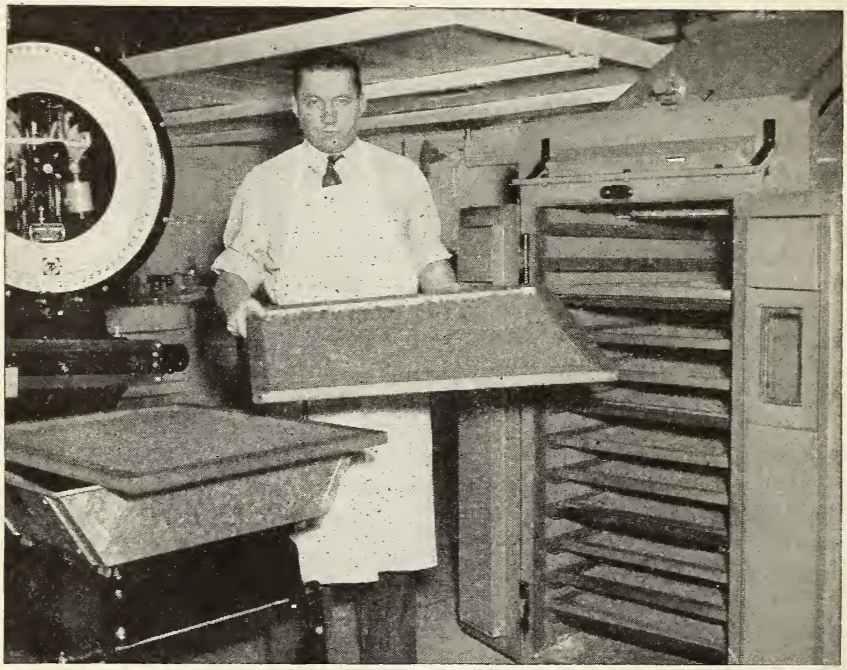

FIGURE 2.—A cabinet dehydrator used in the investigations. The meat is spread on trays exposed to circulating heated air.

The factors affecting drying rate that were studied included fat content of the raw meat, particle size, cooking temperature in the kettle, grinding before or after cooking, and drying temperature.

Although higher fat content of the raw material means less moisture to be removed in drying, in dehydration by the kettle cabinet process a high percentage of fat increased the time required for drying. This was apparently due to the fact that the meat particles became encased in fat, a condition that retarded moisture evaporation. When meat was ground through a plate with holes 1.1 inches in diameter, producing large particles, the rate of drying was much lower than when similar meat was ground through a plate with 0.25-inch holes. Precooking at 212° F., in comparison with 165°, for 30 minutes made little difference in subsequent drying rate. Meat ground after cooking dried almost twice as rapidly as that ground before cooking.

[2] It was recognized that there was considerable interest throughout the country in dehydrators of the tunnel type. However, drying conditions that might be used in a tunnel dehydrator could be provided in a properly designed, suitably equipped machine of cabinet type. Therefore, a dehydrator of the tunnel type was not used in the work. Used in conjunction with the steam-jacketed kettle, this type of dehydrator would constitute a process which could be termed "kettle tunnel."

At 160° and 180° F., the meat required 2 to 6 hours to dry to 10-percent moisture content, depending on fat content, particle size, temperature, and whether the meat was ground before or after cooking. A drying temperature of 180°, in general, speeded up the drying rate over lower temperatures. Air temperatures as high as 200° during the early stages of drying, while the rate of evaporation was still high, appeared to have no harmful effect on the product.

### *Résumé of Kettle Cabinet Method*

The studies indicated that the most favorable conditions for dehydrating meat by the kettle cabinet process were: Cooking meat of 10- to 15-percent fat content, on the raw basis, at 212° F. for 30 minutes; grinding through a plate with 0.25-inch holes; loading on screen trays at the rate of 1.5 pounds per square foot; and drying with air at 180°. The relative humidity of the air in the drying compartment was maintained as nearly as possible at 31 percent. If a drying cabinet is of wood construction, direct heat should, of course, not be used.

## Drum Cabinet Method

Prior to the emergency investigations by the Department, at least one commercial firm had used the double-drum drier for pre-

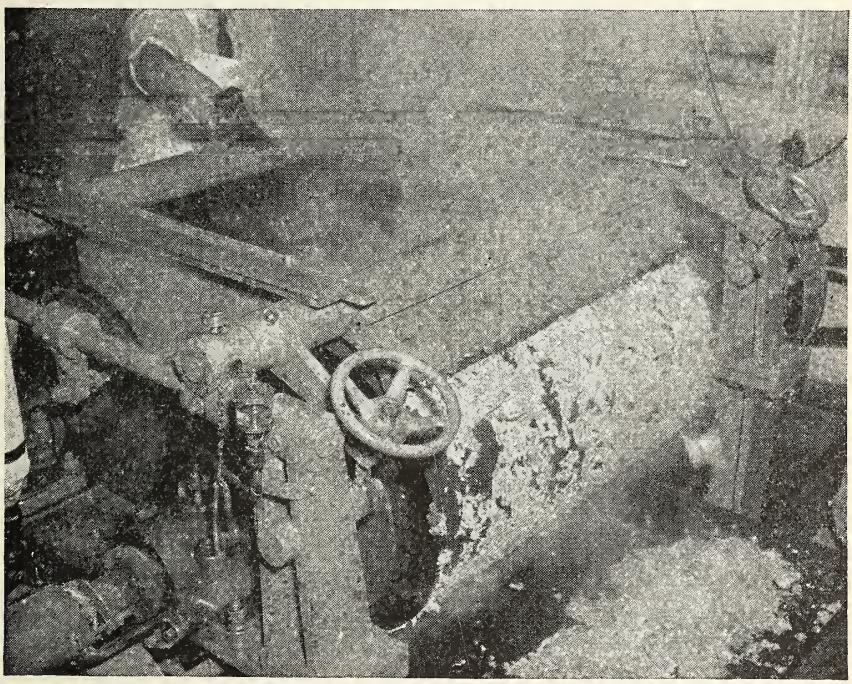

FIGURE 3.—Double-drum drier used for precooking the meat. After passing between two slowly revolving steam-heated cylinders, or drums, the meat is automatically scraped off the surface and falls into the pan below. The next step is dehydration of the meat in a cabinet or other drier.

cooking meat. The Department workers were interested in the possibilities of this type of machine, which utilizes two revolving steam-heated drums, illustrated in figure 3. The drums are set slightly apart, and the meat passes between them as they rotate. The so-called drum cabinet process consists of drum pretreatment combined with cabinet drying.

With air temperatures of 160° to 180° F. in the cabinet dehydrator, drum-cooked meat dried to 10-percent moisture content or less in 1.5 to 6 hours, depending on fatness, size of particle, and whether the meat was ground before or after cooking. Grinding the meat after it cooked on the drums speeded up the drying rate tremendously. Decrease in relative humidity of the air in the cabinet drier hastened the drying rate. At an air temperature of 200° in the cabinet, the meat dried more rapidly than at 180° but tended to darken and scorch. At an air temperature of 140°, the rate of drying was rather slow. Lean meat dried more rapidly than fat meat.

To avoid drip loss in the cabinet drier, the fat content of the raw material should not be more than that required to give about 35 percent of fat in the dehydrated product. Both higher steam pressure in the double drums, resulting in higher temperature, and slower rate of revolution, resulting in holding the meat longer on the drums, tended to speed up the rate of subsequent drying in the cabinet.

### *Résumé of Drum Cabinet Method*

The studies indicated that in dehydrating meat by the drum cabinet method the best results will be obtained by grinding the raw meat through a plate with 1.1-inch holes; using 100 pounds of steam pressure in the drums, making about one revolution a minute; setting the drums 0.1 inch apart; regrinding the cooked meat, through 0.25-inch holes; spreading the meat on screen trays at the rate of 1.5 pounds per square foot; and drying in a cabinet with circulating air at 180° F. Dampers were set to maintain as near 31-percent relative humidity as possible.

## Retort Cabinet Method

It was logical to consider pressure cooking as another means of treating meat preliminary to drying. A retort was obtained, therefore, for use in the Beltsville studies. A cabinet dehydrator was employed in conjunction with this cooker and the combined process was known as the retort cabinet method. In general, the method involved pressure cooking of the meat spread out in shallow pans, grinding the cooked meat without adding the liquid that cooked out, and dehydrating the meat on trays in the cabinet drier.

When meat was cooked under 15 pounds of steam pressure for 60 minutes, it lost more juice and fat than when it was cooked a shorter time, with the result that it dried to a given moisture level more quickly. However, meat of low original fat content dried in about one-half the time required by meat of high original fat content. In one experiment the low fat content was 11 to 12

percent; the high, 17 percent. In another experiment, the low fat content was 15 to 16 percent; the high, 24 percent. With the air temperature in the cabinet dehydrator at 180° F., retort-cooked meat dried to 10-percent moisture content in 2 to 4 hours, depending on its fat content.

Pressure cooking eliminates part of the fat from the meat. If there is an excess of fat in the raw material, this method provides an economical means of separating it from the meat. However, the pressure treatment also cooks out some juice, mixed with the liquefied fat. Generally speaking, to obtain a high-quality product, the juice should be separated from the fat and added to the solid matter.

### *Résumé of Retort Cabinet Method*

The studies indicated that the best results were obtained with the retort cabinet method when the meat was heated under pressure only until cooked throughout, ground through a plate having 0.25-inch holes, loaded on screen trays at the rate of 1.5 pounds per square foot, and dehydrated with air at 180° F. Even with an air temperature of 160° the processing was carried out expeditiously.

## Pretreatment Methods Compared

In a comparison of the several methods of pretreatment—open-kettle, double-drum, and steam-pressure—as applied to pork of 7- to 13-percent fat content, it was found that uncooked meat ground through the plate having 0.25-inch holes and kettle-cooked 45 minutes at 212° F. dried to 10-percent moisture at 180° air temperature in about 4 hours. When ground after being cooked, it dried in about 2 hours. For meat ground to the same size before cooking, then cooked on the double drums and dehydrated, as in the other instances, the time was 5 hours. Finally, when the meat was pressure-cooked for 1 hour, then ground through 0.25-inch holes and dehydrated, the time required to attain 10-percent moisture content was approximately 2 hours. Thus grinding the meat rather finely after cooking materially expedited subsequent dehydration.

## Kettle Air Rotary Method

Two air rotary dehydrators, designated as A and B, were used in the investigations. Both were well-known makes and had been rather widely used in the drying of products other than meat. The problem confronting the industry and the Department was to determine their adaptability for dehydration of meat. One of the makes received much attention from a large packing company that has now adopted it for use in the commercial dehydration of meat. Neither machine was received by the Department sufficiently early in the investigations to permit thorough study.

Air rotary dehydrator A was a small unit suited for operations of only moderate size, rather than for commercial use. It consisted of a cylinder 6 feet long and 1 foot in diameter. Precooked meat to be dried was fed into one end of the drier, which revolved

so that the meat gradually worked its way to the other end, at a rate dependent on the pitch, rate of feeding, and rate of revolution of the cylinder. Air movement was created by means of a small exhaust fan. The pitch, rate of revolution, and air circulation could be controlled. The drier was equipped with eight steam tubes running longitudinally through the cylinder. The steam pressure in the tubes and, therefore, the temperature of the tubes could be varied at will. The meat came into direct contact with the hot pipes and tumbled from one to another as the drier revolved.

Owing to shortage of time, the only variables studied in relation to satisfactory dehydration were rate of feeding, fatness of meat, pitch, rate of revolution of the cylinder, and direction of circulating air. After a series of tests, the rate of feeding was established at about 5 pounds of precooked meat per hour, with the cylinder making 2 1/6 revolutions per minute, with a pitch of 1 inch over the 6-foot length, and with 65 to 70 pounds of steam pressure in the tubes. The air circulation gave best drying rates when running counter to the direction of movement of the meat and with dampers almost entirely closed, thus causing recirculation of most of the air. When the meat contained a large proportion of fat (20 percent or more on the raw basis) it tended to stick on the hot steam tubes, thereby interfering with the heat transfer from the pipes to the remainder of the meat.

With this small unit a difficult cleaning problem was encountered. In a plant-size machine it should be possible to maintain a sanitary condition with greater facility. Any change in the dimensions or structure of the machine would require establishment of other drying conditions. In this unit the meat required about 40 minutes to pass from one end of the cylinder to the other.

Air rotary dehydrator B was a cylinder 6 feet long made up in effect of two shells, one inside the other. The outside diameter of the outer shell was 18 inches. The inner shell containing the meat had openings, or louvers, through which heated air was blown at the rate of 400 cubic feet per minute. The air passing through the louvers toward the axis of the rotating cylinder necessarily passed through the mass of meat. There were dampers for permitting the humid aid to escape or for recirculating it to any extent desired. The cylinder speed varied from 0.5 to 2 revolutions per minute. The machine had a natural pitch of 2.5 inches over the 6-foot length (fig. 4). The air blown through the meat was heated by a bank of five finned steam radiator heaters and entered the drier at about 240° F. When the machine was running at capacity load, the temperature of the exhaust air was about 150°.

The primary objective of the limited work done with this machine was to establish the rate of feeding under a given set of mechanical conditions. After preliminary trials the drier was operated as follows: The speed of the rotating drum was set at one revolution per minute. Since the air velocity was so great (400 cubic feet per minute), the dampers were set so that only a small amount of fresh air entered the machine; the exhaust dampers were set to release the excessively wet air.

The meat to be dehydrated was first kettle-cooked. During

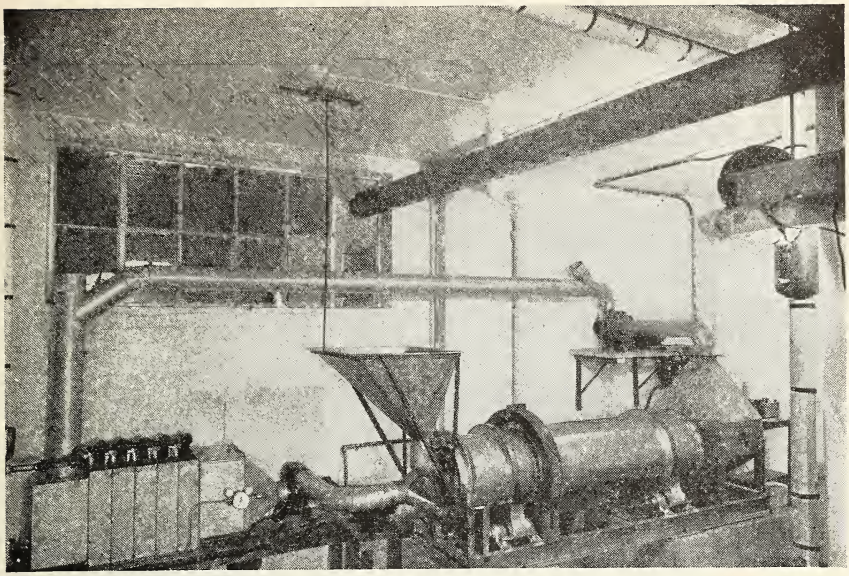

FIGURE 4.—Air rotary dehydrator B, showing heaters on left, feeding hopper in center, rotating cylinder on right center, collecting apparatus for dehydrated meat on right, and air discharge and recirculation ducts above.

this process the excess fat was skimmed off and separated from the juice, and the latter was added to the meat so that only moderately fat meat was dried.

The feeding rate that produced meat dried to a proper moisture content was about 0.75 pound of cooked meat per minute. Another method was to feed 25 pounds of cooked meat into the machine at once and then maintain a feeding rate of 1.5 pounds per minute. The latter procedure, of course, is indicative of the more practical operation. Although it may seem illogical to have used the higher rate of feeding of 1.5 pounds when the machine already contained a load of 25 pounds of meat, the heated air appeared to require a longer time to pass through the meat, thus heating it to a higher temperature and drying it more quickly. The cleaning problem was solved by attaching a cover plate at each end of the cylinder. With these plates in place the machine would retain hot water and washing powder while being rotated.

## *Résumé of Kettle Air Rotary Method*

Studies of meat dehydration by this method involved limited tests of two types of commercial dehydrators that had been used for drying other products. Kettle cooking of the meat preceded dehydration which, in both machines, occurred in a rotating cylinder. Drying was accomplished in one case by contact with steam-heated tubes supplemented with limited circulation of air and in the other by rapidly circulating heated air. The tests provided data on conditions favorable for meat dehydration, in such equipment, including rate of

feeding, pitch and speed of rotating cylinder, amount of steam pressure or temperature of heated air, and control of ventilation by exhaust dampers. The specific values or conditions varied with the type of equipment and were influenced also by the fatness of the meat.

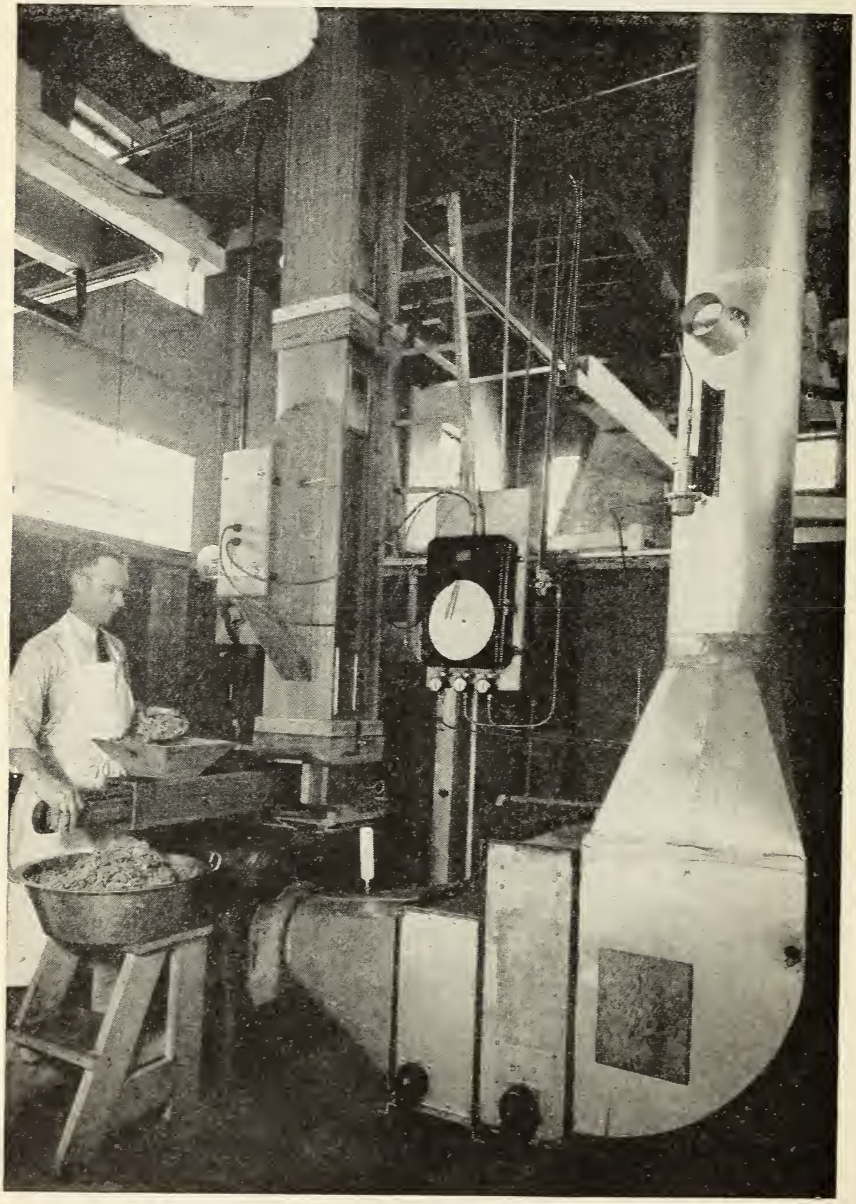

FIGURE 5.—Air flotation dehydrator, showing fan and drying chamber at left, heater and return duct at right. The dehydrated meat, passing out of the drying chamber, is carried into a collector by the moving air.

## Drum Air Flotation Method

Embodying a principle used in certain other fields of dehydration, a machine was designed and built in the Department for its research on meat. Designated as the air flotation dehydrator, it took advantage of the ability of a column of air, moving vertically upward, to float or support particles of meat. The theory was held that as the particles lost moisture to the moving heated air their specific gravity would decrease and they would rise higher and higher in the drying chamber or stack. Finally, at a suitable stage of dryness, they could be blown over into a receiver for the finished product. As constructed at Beltsville, the machine consisted of a steam radiator for heating the air, a motor-driven fan assembly, the flotation or drying chamber, a cyclone collector, connecting duct work, and steam and electric lines (fig. 5).

For precooking, the double-drum drier was used. Thirty-pound lots of pork containing 12 to 13 percent of fat, on the raw basis, ground through the plate with 0.25-inch holes, cooked on the double-drum machine, and dehydrated at an air temperature of 160° to 180° F. attained a moisture content of 9.1 percent in 138 minutes. In the same period of time, 50-pound lots of similar meat were reduced to nearly the same moisture level. This result was in accord with theory. Since an increased load merely required more air to keep the meat afloat and more heat to maintain the air temperature, one would hardly expect weight of load to have an appreciable effect on drying rate. Rather, it would seem to be a matter of capacity as determined largely by the fan and heater.

A noticeable decrease in drying rate occurred with increase in fat content of raw material, but the effect was not nearly so marked as in methods involving cabinet drying. The constant swirling of the meat particles against the inside wall of the flotation chamber appeared to brush off much free fat and decrease the probability of fat encasement. With sufficiently high fat content and air temperature, liquid fat ran down the walls of the chamber.

In a comparison of the effect of particle size on drying, two identical lots of beef were ground through plates having 0.37- and 0.87-inch holes and were then drum-cooked. The smaller particles dried to 8.2-percent moisture content in 90 minutes at 148° F. in the air flotation dehydrator. On the other hand, the larger particles required 115 minutes at 165° to dry to 11.6-percent moisture. Thus, even with drum cooking, which tended to compress all particles to the same thickness, those ground to the larger size had the lower drying rate.

As expected, the drying rate increased with increase of drying temperature. This is clearly shown in table 1, which gives the

TABLE 1.—*Relation between temperature of air in flotation chamber and rate of drying of beef*

| Designation of beef sample | Temperature of air in flotation chamber | Drying period | Moisture content of dehydrated beef |
|---|---|---|---|
| | °F. | *Minutes* | *Percent* |
| A | 120 | 270 | 9.4 |
| B | 140 | 255 | 9.0 |
| C | 160 | 180 | 9.4 |
| D | 170 | 150 | 9.8 |
| E | 180 | 125 | 8.8 |
| F | 200-205 | 77 | 7.2 |

results of an experiment in which six samples of beef were exposed to different air temperatures, other conditions being the same.

One disadvantage observed in the air flotation method was that the continuous whirling of the meat in the chamber caused the shredding and breaking up of about 25 percent of the particles. Another was the loss of fat under some conditions, as previously indicated. On the other hand, this loss suggests the possibility of developing a procedure by which surplus fat might be eliminated economically. Probably the most important remaining problem with respect to this process is its development from a batch to a continuous operation.

### *Résumé of Drum Air Flotation Method*

On the basis of the experimental work, conducted principally with pork, operating conditions regarded as favorable with this equipment were as follows: Pork containing about 15 percent of fat was ground through the plate with 0.25-inch holes and cooked on the double drums operating under 70 pounds of steam pressure, at about one revolution per minute and with 0.10-inch separation of the drums. The cooked meat was transferred to the flotation machine and dried at 170° to 180° F. to below 10 percent of moisture.

## Freezing Cabinet Method

When, at any stage, the dehydrating process involves the use of air temperatures that are high enough to cook the meat and it is later cooked in preparation for consumption, obviously it has been subjected to two cookings. Probably it is too much to expect such meat to have a flavor as desirable as that of meat cooked only once. Thus it was logical to study the possibility of producing a dehydrated raw-meat product having characteristics closely approaching those of fresh meat. Temperatures below the coagulation point of the meat protein appeared to be required, and in that case the keeping quality of the dehydrated product would be a major question.

Instead of being precooked, the meat was frozen, ground, spread onto trays, and placed in the cabinet drier, and air was blown through or across the screen trays. Drying time to give the meat approximately 10-percent moisture content (the limit set for precooked dehydrated meat) ranged from 2 to 11 hours, depending on several factors. The usual operating procedure was to grind the meat coarsely, freeze it at 0° F., regrind it through the plate with 0.25-inch holes, and load it on the trays at the rate of about 1.5 pounds per square foot. Drying was then done at an air temperature of 120° and a relative humidity of 5 to 10 percent, with through circulation, to a moisture content of 3 to 4 percent in about 4 to 5.5 hours.

### *Résumé of Freezing Cabinet Method*

Although the freezing cabinet process appears promising from certain points of view, the quality of meat dehydrated by this method is questionable. Other problems involved in

the use of this method, also, must be solved. Those problems have to do with the possible presence of bacterial toxins and trichinae. It seems probable that only through the use of a relatively low moisture content—not more than 4 percent and perhaps as low as 2 percent—could enzymatic action be sufficiently retarded. Further research will be required to obtain more definite information in regard to the keeping quality and certain other characteristics of meat dehydrated by the freezing cabinet process.

## PACKAGING

Containers to be used for dehydrated meat should protect against light and vermin, including insects, and be able to withstand rough handling and temporary immersion in fresh or salt water. They should also exclude air and moisture-vapor and should be impermeable to fat; resistant to the transmission of foreign substances, odors, or flavors; light in weight; compact, and easy to handle; and available under war conditions.

Strength, lightness, and compactness are essential when shipments are to be made to places where modern transportation facilities are limited and reliance must be placed on primitive transportation—pack animals, for example. Rectangular containers make full use of all space, whereas approximately one-fifth of the shipping space required by cylindrical containers remains unoccupied. In wartime, the availability of suitable packaging materials is an important consideration in the selection of packages. Steel and tin for cans are limited, and manufacturers of paper and metal-foil containers have experienced difficulties in obtaining suitable paper stock, laminating and adhesive materials, and metal foil in the quantities needed.

A study of many kinds of metallic and nonmetallic packages in relation to these factors was made. The experiments were conducted both at the Beltsville Research Center, Beltsville, Md., and in cooperation with the University of Chicago and the American Meat Institute, at Chicago, Ill. As a means of evaluating different containers, such determinations as peroxide value (indicating oxidative action), free acidity, moisture, gas analysis, and palatability were made. Samples of dehydrated meat were stored at temperatures of 0°, 50°, 70°, 110°, and 135° F. For studies of moisture absorption at temperatures of 50° to 110°, a constant relative humidity of 80 percent was maintained.

### Tests with Metal Cans

When high-quality samples of dehydrated meat containing fat of good stability were packed and stored in cans at moderately low temperatures, they had excellent keeping quality. After 2 to 4 weeks of storage at 110° and 135° F., the samples developed a flavor resembling that of cured meat and the color became a marked red. After 6 months of storage at 135°, samples of canned dehydrated meat developed a scorched or overcooked flavor, and samples at 110° developed an overcooked flavor in 11 to 12 months. But those samples stored at room temperature and

under refrigeration had changed little in flavor or color after 12 months of storage.

No difference was noted in the keeping quality of meats packed in hot-dipped tin-plate cans (1.25 pounds of tin per base box, a unit of area for tin plate), fused electrolytic tin-plate cans (0.5 pound of tin per base box), or "Bonderized" cans, made by a patented process that eliminates the use of tin. When the dehydrated product was of good quality, samples air-packed in cans were practically as good as those packed in vacuum or nitrogen in the same kind of container.

## Tests with Paper and Metal-Foil Packages

A representative group of the paper and metal-foil packages was studied with a view to determining their suitability as substitutes for cans. The materials, laminating agents, and sealing compounds varied with different makes of bags, which were of the envelope type—flat bags which when opened become containers with rectangular sides. These bags were approximately 5½ by 8½ inches in size and when filled were fitted into cartons.

A brief description of this class of containers follows:

A. 55-pound laminated glassine; thermoseal tops and bottoms.

B. 25-pound glassine, 300 M.S.A.T. (moisture-proof, heat-sealing, anchored, transparent) cellophane; two side seals. (The term "anchored" signifies a process by which the heat-sealing material is firmly fastened to the cellophane.)

C. 45-pound opaque glassine and 300 M.S.A.T. cellophane laminated together with the cellophane inside; two side seals.

D. A double thickness of 450 M.S.A.T. cellophane laminated together; two side seals.

E. Asphalt-impregnated kraft, 0.0005-inch lead foil, and 300 M.S.A.T. cellophane laminated together with the cellophane inside; two side seals.

Many other special packages were tested. Some had stitched closures; some were wax dipped; many were fabricated with special laminating agents and heat-sealing compounds.

A thorough study of the five types of paper and metal-foil packages described showed types A and B to be unsatisfactory. Types C, D, and E, when fabricated with suitable laminating and heat-sealing materials, were the best substitutes for cans. Package C was improved when 55-pound glassine and 450 M.S.A.T. cellophane were used. The best over-all results, for these classes of containers, were obtained with package E.

Many containers of types C, D, and E were filled with dehydrated pork and stored at temperatures of 0° to 135° F. In general, packages C and D held the meat in good condition at 110° and 80 percent humidity for 4 to 6 months, when the experiment was terminated. Container E was satisfactory up to 6 months of storage under the same conditions.

A number of packages of all kinds were stored at alternated temperatures, a method of testing known as cycling. Some were cycled between 0° and 110° F., and others between 50° and 110°.

All were alternated on a 24-hour cycle. The relative humidity on the 50° to 110° cycle was 80 percent. A majority of the containers cycled at both ranges failed after 45 to 55 cycles. Apparently the temperature variations caused the different layers of the bag material to contract and expand at different rates and to different degrees. The stresses thus developed caused separation at the heat seals and tearing of the material. The packages would probably withstand natural temperature variations for a longer period before break-down.

Tests of different types of packages showed that to prevent oxidation of the fat and absorption of moisture, dehydrated meat must be packed in air-tight containers. A good-quality product, signifying one in which little or no oxidation has occurred, was capable of absorbing, without appreciable deterioration, the small amount of oxygen sealed in the container when the meat was packed in air. However, the transmission of additional air through containers that were not air tight accelerated oxidation.

## Gas Analyses

A number of gas analyses were made of dehydrated pork and beef packed in tin cans and sealed in an atmosphere of air, and also of pork packed in other types of containers. In dehydrated pork packed in cans the oxygen content of the gas decreased from 21 percent to 1 percent in 2½ weeks at room temperature, and then slowly decreased to 0 percent in 10 weeks. At the same time the carbon dioxide content of the gas increased to 1.5 percent. In cans of dehydrated beef, the oxygen decreased to 1 percent in 8½ weeks and to 0 in 14 weeks, and the carbon dioxide content of the gas increased to 3.5 percent. When gas analyses were made on samples of pork stored in paper and metal-foil containers for 3 months or more, many were found not to be oxygen tight. Package E was the most resistant to oxygen penetration, but 50 percent of the containers tested showed leakage, apparently through the side and end seals.

Since the moisture content of dehydrated meat should at no time exceed 10 percent and since additional oxygen leads to oxidation, a container for dehydrated meat should exclude both moisture-vapor and air.

## Other Packaging Studies

Packaging materials used for dehydrated meat should likewise be impermeable to fat. Tests of a group of more than 20 different kinds of nonmetallic packages, all of which failed, indicated that the adhesive, the laminating agent, and the heat seal must all be insoluble in fat. Various kinds of paper packages were tested after being dipped in wax or gelatin. It was found that, if the inner bag was tight, the coating applied by dipping was unnecesary and if the inner package leaked, the wax or gelatin did not protect the contents.

Experiments with nonmetallic packages showed that sometimes foreign substances, odors, or flavors were imparted to the meat from the package. By proper selection of the laminating and

coating material used in making the paper sheets, this trouble could probably be avoided.

Spectrographic studies to determine the extent to which dehydrated meat could be contaminated with lead from the lead foil of package E were carried out. Twenty-four packages, with and without a special inner glassine liner, filled with dehydrated pork, were shipped 5,000 miles by rail. Under the conditions of the experiment no lead contamination from the package took place.

### *Significant Results of Packaging Studies*

Properly sealed cans fulfill the packaging requirements of dehydrated meat better than any other tested container. The safest policy, therefore, is to use cans as containers as far as possible. It is desirable but not essential to replace the air in the container by nitrogen or a vacuum in order to maintain high quality in the meat.

The envelope-type bag is perhaps the best substitute for cans. The most satisfactory container of this kind tested was the lead-foil bag designated as container E. There are probably many combinations of cellophane, glassine, and kraft paper, with or without metal foil, that have low enough water-vapor and oxygen permeability to make a satisfactory container. However, the chief cause of failure in packages of this type appeared to be leakage through the heat-sealed closure and sides. This may be overcome as the rapidly developing paper-container industry improves its facilities for commercial production of bags of uniform quality and tightness.

A well-made nonmetallic or metal-foil paper package may be expected to give satisfactory performance up to about 6 months when filled with a good grade of dehydrated meat, subjected to careful handling, and kept under moderate storage conditions in a temperate climate.

## COMPRESSIBILITY

Since a major purpose of dehydrating meat is to save shipping space, full advantage should be taken of any opportunity for compressing the product into a smaller volume after it has been dehydrated (fig. 6). Moreover, air is removed by compression and consequently the oxidation processes, in part responsible for the development of rancidity, are retarded.

When the Department began its research there seemed little doubt that the density and temperature of the dehydrated product at the time of compression were major factors influencing compressibility. Density was believed to depend largely on particle size and shape as well as on fat content. The first study involved relatively low-fat (approximately 27 percent) and high-fat (approximately 36 percent) dehydrated pork samples, both of 0.25-inch grind and processed by the vacuum rotary method, with relative densities of 0.60 and 0.85, that is, weighing 60 and 85 percent as much as the same volume of water. At a given pres-

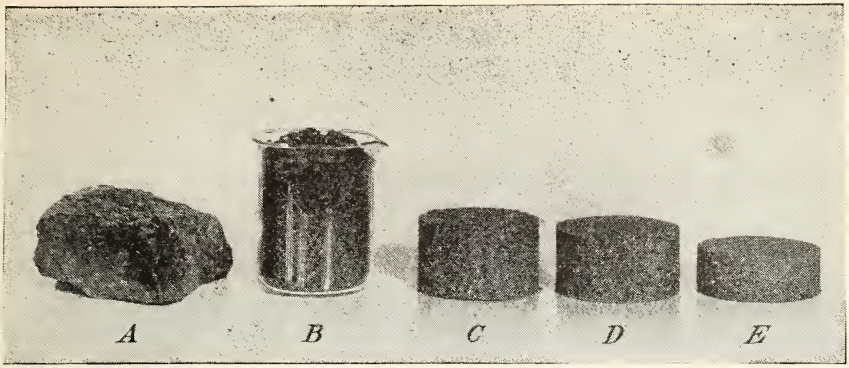


FIGURE 6.—*A*, Raw, unground pork; *B*, the dehydrated, uncompressed equivalent; *C*, *D*, and *E*, the same amounts of dehydrated meat compressed at 100, 300, and 600 pounds of pressure per square inch, respectively. The corresponding volumes of the meat in the five different forms were 215, 153, 94, 77, and 61 cubic centimeters.

sure there was greater density after compression in the high-fat product than in the low-fat product. In the low-fat and high-fat samples under 225 pounds of pressure per square inch, the respective decreases in volume were about 38 and 28 percent and the respective densities of the compressed samples 0.97 and 1.13. The low-fat sample lost no fat up to approximately 750 pounds of pressure, but the other sample lost about 1 percent under 75 pounds of pressure and approximately 4.5 percent under 300 pounds.

In another test a comparison was made of particles ground through plates having 0.25 and 1.1-inch holes, both samples being of high fat content and produced by the vacuum rotary method. The respective densities, uncompressed, were 0.85 and 0.60. At a given pressure there was greater density in the product of smaller particle size than in that of larger particle size. Both samples attained their maximum density at about 225 pounds of pressure. The respective decreases in volume at that pressure were approximately 28 and 45 percent.

In general, at pressures ranging from 75 to 300 pounds the greatest density was attained by samples of comparatively high fat content and small particle size. However, even at 75 pounds there was a loss of about 1 percent in weight from such samples owing to pressing out of fat.

A study was made of four drum cabinet samples that varied in particle size and fat content. The range of original density of the dehydrated meat was from 0.43 to 0.45. The densities of all four samples increased at about the same rate under pressures ranging from 75 to 600 pounds, but the high-fat samples of both large and small particle size reached maximum density at 450 pounds of pressure, whereas 600 pounds was required for the two low-fat samples. There was noticeably less fat loss from the two samples of the smaller particle size. Decreases in space requirements were all approximately 50 percent at 225 pounds of pressure

and 60 percent at 600 pounds. This work was done with the product at a temperature of about 78° F.

When the same four drum cabinet samples were compressed at 38° F., only small differences between the densities and the decreases in volume were observed, as compared with corresponding samples compressed at 78°. However, no fat loss occurred from three of the samples, even at 600 pounds of pressure. The sample high in fat and composed of large particles lost about 4 percent in fat at 450 pounds of pressure and 5 percent at 600 pounds.

No great change in the texture of the dehydrated meats was observed following compression at the pressures given. An increase in water-absorbing ability signifying rehydration capacity, observed with drum cabinet samples after compression, was probably due in part to the crushing effect on the particles but also to the pressing out of some fat.

### *Significant Results of Studies of Compressibility*

Besides saving shipping space the compression of dehydrated meat improved its keeping quality by retarding oxidation. The experiments indicated that the pressure required to increase the density of dehydrated meat to 1.0, a desirable goal, depends on both the density of the uncompressed product and the temperature of pressing. Less pressure was required for a product of high original density, characteristically of high fat content and small particle size, and when compressing was done at a relatively high temperature. At the higher temperature there was a greater tendency for fat to be pressed from the product. However, this should present no great difficulties under plant conditions, provided there are facilities for compressing directly in the container.

## CONTROL OF BACTERIA AND MOLDS

Information concerning the microbial flora of dehydrated meat, particularly in relation to its keeping quality and wholesomeness, was regarded as an essential phase of the investigations. The studies likewise involved conditions under which dehydrated meat could be safely reconstituted and utilized. The Department of Bacteriology and Parasitology of the University of Chicago cooperated in this part of the work. In the course of the experiments the meat was subjected to various temperatures after which it was examined to ascertain the kinds and numbers of organisms present.

Bacterial spores, although few in number, were the predominating micro-organisms found in the dehydrated product. Gas-forming bacteria that thrive at moderate temperatures (about blood heat) and putrefactive anaerobic bacteria were also found. Other organisms developed at higher temperatures (122°-131° F.), especially after incubation of meat reconstituted with sterile water. Part of the bacterial growth was attributable to conditions of processing and part was carried over from the fresh meat with little change.

Some methods of processing destroyed large numbers of organisms. Particularly striking was the effect of precooking, prior to drying, at 165° F. for 30 minutes. This procedure completely eliminated the large numbers of predominating micrococci found in fresh meat. In fact, studies showed that a temperature of 140° for a minimum of 25 minutes was sufficient to destroy a food-poisoning strain of *Staphylococcus aureus* experimentally inoculated into fresh pork.

The dangers from food-poisoning bacteria appeared to be controlled primarily by the low moisture content of the meat. Food-poisoning strains of *Staphylococcus* and *Streptococcus* failed to grow in the meat as long as the moisture content did not exceed 20 to 30 percent; similarly, strains of *Salmonella* did not grow in meat containing 50 percent moisture or less. Toxin formation from *Clostridium botulinum* occurred only in meat to which sufficient water had been added to make the moisture content more than 30 percent. At a moisture content of 60 percent the meat required an incubation period of less than 48 hours for the toxin to develop. At room temperature, 8 to 10 hours was required for this toxin to be formed in reconstituted meat to which had been added a washed and heated spore suspension of a potent strain of *Clostridium botulinum* isolated from dried meat.

The numbers of bacteria in dehydrated meat usually decreased with the lengthening of the period of storage, the greatest destruction taking place at high storage temperatures. There was also some evidence that an increase in time and temperature of storage, within moderate limits, had a tendency to increase the potency of the toxin developed later from the surviving botulinum spores if they had an opportunity to function.

Visible mold growth appeared to depend on the fat and moisture content of the dehydrated meat and the humidity of the atmosphere to which it was exposed. Lean meat containing less than 10 percent of moisture and heavily inoculated with mold spores required 3 to 4 weeks of storage at 80-percent relative humidity to develop visible mold, whereas less than a week was needed at 100-percent relative humidity. Mold grew with difficulty on fat meat even under most favorable conditions. The size of particle of dehydrated meat also materially influenced the rate at which humidity changes affected the moisture content of the meat. Seldom did mold growth appear on dehydrated meat containing less than 15 percent of moisture.

### *Significant Results Regarding Microbial Flora*

On the basis of the experimental work, dehydrated meat was safe, from a bacteriological point of view, when produced in accordance with the Federal specifications for the product. These included the standard precooking treatment of "a minimum of 30 minutes at not less than 165° F. internal temperature" and a moisture content of the dehydrated product that "does not exceed 10 percent in any particle when placed into the container." The results indicated, in fact, that there was an appreciable margin of safety in the precooking requirement.

Dehydrated meats stored under conditions unfavorable for mold growth, as previously indicated, should offer no opportunity for contamination or growth of food-poisoning bacteria. Reconstituted meat should be consumed promptly, since tests showed it to be an excellent bacterial medium. A good precautionary rule for products containing reconstituted dehydrated meat is to cook them thoroughly, to a degree equivalent to boiling, and to serve promptly.

## CHEMICAL COMPOSITION AND CHANGES

Two principal factors affect the chemical composition of the raw material used in meat dehydration. One is the fatness of the animal or carcass selected; the other is the extent to which fatty tissue is trimmed away from the lean tissue. The processor can drastically influence the composition by attention to these two factors. Relatively lean animals are ordinarily used and little trimming is done on account of the expense involved. Following is a typical analysis of fresh, trimmed pork ready for drying: Moisture, 65.3; protein, 18.8; fat, 15.0; and ash, 0.9 percent. Dehydrated to 10 percent of moisture, with no fat loss in processing, such meat should yield a finished product containing approximately 48.7 percent of protein, 39 percent of fat, and 2.3 percent of ash.

As indicated, the composition of the finished product is influenced by the composition of the raw material, extent of drying, and any losses in constituents other than moisture that occur during the processing. Assuming that the composition of raw material and the moisture content of the dehydrated product can be controlled, the problem becomes one relating to possible losses in protein, fat, or ash. With no discarding of juice and no overheating of the meat, protein and ash values should be retained in full. However, fat losses may be associated with methods of processing and handling.

Of the various general methods of dehydration previously discussed, the vacuum rotary, kettle cabinet, drum air flotation, kettle air rotary, and drum cabinet processes were represented by sufficiently large numbers of samples to justify a study of the composition of the finished product as affected by the process itself. The mean composition of the raw-meat samples representing each of the five methods was used as a basis for calculating the expected composition of the finished product. That composition was then studied in relation to the actual composition of the dehydrated meat.

In all five cases the situation was essentially one of fat loss counterbalanced by a corresponding increase in the percentage of protein or of both ash and protein. Considerable variation occurred, the greatest fat loss being associated with the air flotation process and the smallest loss with the drum cabinet process. The relatively heavy loss in the case of the air flotation process was due largely to the fact that liquid fat accumulated on and ran down the inside wall of the flotation chamber while the drying was in progress. The small loss in the case of the drum cabinet method

probably was due to the slight dripping of fat from the drum or trays or both.

Since this work was done with laboratory or pilot-plant equipment, the fat losses associated with the different processes would not necessarily occur to the same extent in commercial plants. However, the experimental results show that losses are likely to occur and suggest precautions that the processor may take to prevent them.

For eliminating surplus fat in dehydrated meat there is natural interest in procedures less costly than trimming, that may be used as a part of the process or as a final step following the actual drying. The experimental results suggest means already described—such as air flotation—by which some fat can be eliminated during processing. Another method is to collect the combination of juice and fat that comes from the meat in kettle and retort precooking, to separate the fat from the juice, and to add only the latter to the meat. Draining with or without suction, pressing, and using the expeller type of machine involving continuous operation are possible methods for removing surplus fat after drying is completed. Any method used must be under controlled conditions with respect to temperature and other factors.

The chemical composition of dehydrated meat is predetermined to a great extent by specifications for moisture and fat content. With 10 percent of moisture, 30 percent of fat, and 3.5 percent of sodium chloride (common salt) in dehydrated beef—which would be in line with maximum allowances under the specifications adopted by the Department of Agriculture for use in the lend-lease purchase of that product—the protein and natural ash would be approximately 54 and 2.5 percent, respectively. In pork, with moisture and fat at 10- and 40-percent levels—also in line with limits set in Department specifications—the protein and ash would be about 47.5 and 2.5 percent. It is readily apparent that any decrease in percentage of protein in dehydrated meat is largely accounted for by increase in percentage of fat, and vice versa. Therefore, if a primary purpose in using the product in the diet is to furnish a large proportion of the protein requirement, high fat content will tend to defeat that purpose.

## Protein Break-Down in Stored Products

Since one of the chief objects of dehydrating meat is to enable it to keep without refrigeration, the experiments on storage involved the use of high temperatures, well up in the ranges to which the meat may be exposed under tropical conditions or in cargo space aboard ship. Experimentation showed that when dehydrated pork, mutton, or beef is stored at 110° F. a distinct reddish color appears. This is readily distinguishable from the orange to yellow color that develops in rancid pork. The reddish coloring matter is somewhat water soluble, whereas the yellow coloring matter is fat soluble.

Developing with the reddish tinge are flavors that meat judges designate by such terms as "overcooked," "scorched," and "browned." The flavors developed in the early stages of storage may sometimes add to the palatability of the meat, but they are

usually considered undesirable and reduce the rating of the meat in quality.

These changes in color and flavor appeared in various types and qualities of meat in different kinds of packs. They have been observed in both vacuum- and nitrogen-pack cans, in containers permeable to oxygen, in meats of high and low resistance to oxidation and under other conditions, indicating that the fat fraction of the dehydrated meat was not directly concerned. During high-temperature storage, increases in certain compounds derived from proteins, a greater intensity in the color of the aqueous extracts, and change in degree of acidity all indicated that the protein portion of the dehydrated meat suffered from the effects of heat. The general term "protein break-down" used here refers to these changes.

A number of determinations were undertaken on dehydrated meats stored at high temperatures in an effort to find a chemical or other method for estimating the extent of protein break-down. Such measurements included: (1) The quantity of free ammonia that was formed during the break-down process; (2) tyrosine values, based on changes in the amino acid content resulting from the decomposition of protein; and (3) the optical density of extracts of dehydrated meats. When protein break-down occurred, palatability scores by meat judges generally were low, such terms as "scorched" being reported when free ammonia, tyrosine values, and the optical density of the extracts rose. It was concluded that these measurements probably are related to meat quality as affected by protein break-down.

## Oxidation and Rancidity

From the time the animal is slaughtered until after the dehydrated meat is packaged, oxidation proceeds though generally at a slow rate. Prolonged storage, especially under unfavorable conditions, may result in that unpalatable state known as rancidity. Tasting is the only sure method of detecting it. The purpose of this phase of the studies was to determine the extent of oxidation during the various steps of dehydration, how rancidity could best be prevented, or how long the dehydrated meat could be kept under certain conditions before rancidity developed.

Occasionally during the experiments, a process that ordinarily produced dehydrated meat of high stability, signifying resistance to break-down, produced a product low in this respect. Age of raw meat appeared to be the variable factor concerned. The fresher the meat used for drying, the less had been its exposure to atmospheric and enzymic oxidation. Oxidative enzymes are destroyed by a sufficiently high temperature in the processing, but in spite of this oxidation can continue.

Considerable deterioration may occur in the drying stage of processing. For example, in an experiment in which a uniform batch of raw meat was divided into portions that were simultaneously dried by five different processes and subsequently exposed to oxygen at 110° F., the final products varied from high stability, or high resistance to the development of rancidity, in some cases,

to rancidity in others. The extent of oxidation that occurs in a particular process partly determines its suitability for use.

Even the use of an air-tight container for dehydrated meat does not necessarily end the oxidation process. Within the container is some air that allows the process to continue until absorption is complete. Experiments indicated that dehydrated meat can be compressed to a density approaching 1.2 for a tightly packed product as compared with about 0.4 for a similar product loosely packed. At densities of 1.0 and 0.4, the corresponding amounts of oxygen in the space between the particles are calculated to be 0.05 and 0.47 milligram per gram of meat. Meat of low stability may become rancid in the presence of even these small quantities of oxygen, but meat of high stability may absorb considerably more oxygen than the residual quantities in an uncompressed air pack and still not become rancid. The value of compressing dehydrated meat to a density of 1.0 or more is evident, since the less residual air—and therefore oxygen—it contains, the less opportunity there is for oxidation.

Packaging dehydrated meat in nonmetallic containers more or less permeable to oxygen resulted in more extensive oxidation than packaging in cans.

Another line of experimentation dealt with the use of antioxidants—substances that reduce oxidation and thus have prospective value in preventing rancidity in meat products. One of these substances was gum guaiac. Favorable results have been reported from its commercial use in retarding deterioration in lard.[3]

Dissolved in alcohol the gum guaiac was sprayed on the cooking meat while the latter was being well agitated. In all these experiments the meat was derived from uniform lots, and processing was identical in all details.

TABLE 2.—*Effect of varying proportions of gum guaiac on stability of dehydrated pork, as measured by delayed oxidation*

| Percentage of gum guaiac added | Stability in oxygen at 158° F.[1] | Stability in oxygen at 110° F. | |
|---|---|---|---|
| | | Time when rancidity was first detected | Oxygen absorption per gram of meat when rancidity was first detected |
| | *Hours* | *Hours* | *Milligram* |
| 0.070 | 257 | 473 | 0.53 |
| .030 | 175 | 670 | .83 |
| .015 | 116 | 214 | .32 |
| .005 | 101 | 214 | .44 |
| .000 | 18 | 41 | .25 |

[1] Time required, owing to absorption of oxygen by the meat, for decreased pressure in a closed system containing meat sample and oxygen to lower column of mercury 100 mm.

Table 2 shows the effect of using varying proportions of gum guaiac in dehydrated pork. As little as 0.005 percent had a pronounced effect in protecting the meat from the development of rancidity. The table also shows a general agreement of stability tests at the two temperatures, 158° and 110° F. It is noteworthy that the oxygen absorption data are valuable in detecting differences in tendency to become rancid.

In another experiment a sample treated with 0.08 percent of gum

[3] Uses of gum guaiac in relation to fats and oils are described in U. S. patent numbers 1,903,126 and 2,308,912.

guaiac and held in oxygen at 110° F. showed no rancidity, detectable by taste, before 1,172 hours. The control sample became rancid within 20 hours. A similar sample treated with lecithin and ascorbic acid palmitate showed an appreciable antioxidative effect that was amplified by the addition of alphatocopherol.

As a further step, study was made of the effects of gum guaiac and certain other antioxidants on vitamin retention by dehydrated pork during storage at about 70° F. for as long as 9 months. With thiamine, riboflavin, and niacin considered, the results indicated that antioxidants may have an important effect in this respect.[4] In one test more than three times as much thiamine was found in the gum guaiac-treated product after storage for 9 months in container E, described under Packaging, as in that which was untreated and similarly packaged.

From a food standpoint the reader is cautioned that any substances judged to have value as preservatives must comply with laws and regulations governing their use. The quantities of such products added to foods when permitted must usually not exceed specified limits, and there must be an even distribution of the substance to prevent excessive amounts in any portions of the food.

### *Significant Results of Chemical Studies*

The specifications for moisture and fat content determine, to a great extent, the chemical composition of dehydrated meat. Moreover, fat and protein are present in the largest proportions and any decrease in one leads to an increase in the other.

When dehydrated pork, beef, and mutton are stored at a high temperature, such as 110° F., they develop a reddish color. With it, there are "overcooked," "scorched," or "browned" flavors. These changes in color and flavor are regarded as indications of protein break-down.

Freshness of raw material, together with conditions of processing, packaging, and storing that reduce exposure to air, aids in obtaining good keeping quality. Gum guaiac added in small proportions is a further aid.

## NUTRITIVE VALUE OF PROTEIN AND FAT

Protein studies involved 16 lots of pork, 18 of beef, and 4 of mutton. By the time this work was undertaken, commercial production of dehydrated meat was in progress and both commercial and experimental products were tested. In addition, one lot each of dried skim milk and of dried eggs was tested for comparison. Young white rats were used as test animals. Each diet was adequate in all respects, including quantity of protein; the source of protein was the variable factor.

A general comparison of the growth-promoting values and digestibility of the protein of several dehydrated meats and other foods is provided by the data in table 3.

[4] These vitamin determinations were made at the United States Plant, Soil, and Nutrition Laboratory, located at Cornell University, Ithaca, N. Y.

TABLE 3.—*Comparison, by rat-feeding tests, of the growth-promoting value and digestibility of the protein in dehydrated meats, produced by various processes, and in other protein foods*

| Food | Gain in weight of rats, in 30 days, per gram of protein consumed on 10-percent feeding level | | Digestive coefficient[1] | |
|---|---|---|---|---|
| | Range | Average | Range | Average |
| | *Grams* | *Grams* | *Percent* | *Percent* |
| Dehydrated pork | 2.68-3.72 | 3.35 | 90.2-93.2 | 92 |
| Dehydrated beef | 2.42-3.63 | 3.15 | 83.3-91.4 | 88.7 |
| Dehydrated mutton | 3.16-3.24 | 3.2 | 90.5-91.5 | 90.9 |
| Dried skim milk | ------ | 3.15 | ------ | 80.3 |
| Dried eggs | ------ | 4.28 | ------ | 89.4 |

[1] Proportion of protein not excreted in the feces.

In some instances the growth-promoting values and the digestive coefficients of the protein differed significantly between lots of dehydrated meat. The significant differences in the former may be attributed to the quantity of connective tissue in the raw meat, the maximum temperature during the processing, and the duration of exposure to such temperature. The protein in dehydrated meat is most nutritious when the raw meat contains a minimum proportion of connective tissue and when the meat is dehydrated as rapidly and at as low a temperature as practicable. The results of these experiments indicate that, for the most part, the digestive coefficients for the protein in dehydrated meat compare favorably with those previously reported for meat in general.

Experiments were also conducted to determine the effects of storage on the nutritive value of the protein of dehydrated pork at different temperatures for different periods of time. The results were inconclusive as regards the growth-promoting value of the protein, but the digestibility was not materially affected by storage for 112 days at temperatures ranging from 0° to 110° F.

In a study of the effects of dehydrated pork, as the chief source of protein in the diet, on growth and reproduction in rats, samples from two commercial meat-packing plants and two lots prepared at Beltsville were used. Five diets containing dehydrated pork and one stock diet were fed to six groups of 12 young female rats each; a group of 12 young males was also fed the stock diet. Each diet contained approximately 21 percent of total protein. The results indicated no material difference in the growth-promoting properties of the different diets during a period of 60 days, beginning when the rats were 28 days old.

The female rats of each group were mated when about 90 days old and again after the first litters had been weaned. The results of these tests indicated satisfactory reproduction from four groups of rats fed diets containing dehydrated pork as compared with the rats fed the stock diet. Reproduction results from one sample of commercial dehydrated pork and from a sample of dehydrated pork prepared at Beltsville were unsatisfactory.

Another experiment was conducted to determine the effect of the storage of dehydrated pork for 168 days at 0°, 70°, and 110° F., on the digestibility of the fat. Satisfactory values similar to those previously determined for lard were obtained.

### *Significant Results of Studies on Nutritive Value*

In general, the results of these experiments indicate that the protein in dehydrated pork, beef, and mutton is of relatively high nutritive value when properly prepared from suitable raw material.

## VITAMIN AND MINERAL CONTENT

Experiments were conducted to determine the efficiency of certain processing methods with respect to greatest retention of thiamine, riboflavin, and nicotinic acid, and iron and phosphorus. These nutrients were selected for study because meats are important sources of them.

The work was devoted largely to a detailed study of two types of processes that were of interest because of their adaptability for commercial use. They were the vacuum rotary and kettle cabinet methods. Several different lots of meat were used and several processing runs were made for the purpose of these experiments.

Two lots of stored pork were also analyzed. One of these was dehydrated by a commercial firm and the other in the Beltsville laboratories. Both were packaged in container E (described under Packaging). The samples were stored at 0°, 70°, 110° F., and temperatures alternating between 50° and 110° on a 24-hour cycle for 8, 24, and 36 weeks for the commercially dehydrated meat, and 8 weeks for the experimentally processed sample. A constant relative humidity of 80 percent was maintained at all storage temperatures except 0°.

In this work on vitamin and mineral content, beef and pork were studied, the greater emphasis being on pork because of the probability that much more of that meat than of beef would be dehydrated in the United States. Representative samples at various stages—raw, precooked, freshly dehydrated and stored—were used. Moreover, the raw and dehydrated meats were analyzed after cooking by use of the standard methods developed for the palatability tests.

A summary of the results is presented in tables 4 and 5. The data in table 4 on the vitamin content of meats processed by the vacuum rotary and kettle cabinet methods indicate that during dehydration losses usually occurred in nicotinic acid, riboflavin, and thiamine, in varying degrees. The nicotinic acid and riboflavin losses were relatively small. The most marked effect of these two dehydration processes was on the thiamine content. The average losses in thiamine during the entire processing procedure were about 43 and 53 percent. Differences in the methods of precooking may be responsible for the differences in these results.

The proportions of phosphorus did not undergo much change. There were some increases in the iron content, acquired no doubt from the equipment used in processing.

TABLE 4.—*Vitamin and mineral contents*[1] *of raw and dehydrated beef and pork and changes in these constituents due to dehydration by 2 methods*

| Method of processing | Kind of meat | Samples | Nicotinic acid | | |
|---|---|---|---|---|---|
| | | | In raw meat | In dehydrated meat | Gain (+) or loss (−) |
| | | *Number* | *Mg. per 100 gm.* | *Mg. per 100 gm.* | *Percent* |
| Vacuum rotary | Beef | 4 | 19.6 | 15.2 | −22.0 |
| | Pork | 12 | 15.4 | 15.9 | +3.0 |
| Kettle cabinet | Beef | 2 | 12.4 | 10.7 | −14.0 |
| | Pork | 11 | 10.1 | 8.6 | −15.0 |

| Method of processing | Kind of meat | Samples | Riboflavin | | |
|---|---|---|---|---|---|
| | | | In raw meat | In dehydrated meat | Gain (+) or loss (−) |
| | | *Number* | *Mg. per 100 gm.* | *Mg. per 100 gm.* | *Percent* |
| Vacuum rotary | Beef | 4 | 0.96 | 0.68 | −29.0 |
| | Pork | 12 | 1.10 | .95 | −15.1 |
| Kettle cabinet | Beef | 2 | 1.77 | 1.53 | −13.3 |
| | Pork | 11 | 1.85 | 1.69 | −8.5 |

| Method of processing | Kind of meat | Samples | Thiamine | | |
|---|---|---|---|---|---|
| | | | In raw meat | In dehydrated meat | Gain (+) or loss (−) |
| | | *Number* | *Mg. per 100 gm.* | *Mg. per 100 gm.* | *Percent* |
| Vacuum rotary | Beef | 4 | ---- | ---- | ---- |
| | Pork | 12 | 2.70 | 1.56 | −42.5 |
| Kettle cabinet | Beef | 2 | ---- | ---- | ---- |
| | Pork | 11 | 2.32 | 1.09 | −52.8 |

| Method of processing | Kind of meat | Samples | Phosphorus | | |
|---|---|---|---|---|---|
| | | | In raw meat | In dehydrated meat | Gain (+) or loss (−) |
| | | *Number* | *Gm. per 100 gm.* | *Gm. per 100 gm.* | *Percent* |
| Vacuum rotary | Beef | 4 | 0.692 | 0.676 | −2.3 |
| | Pork | 12 | .650 | .652 | 0 |
| Kettle cabinet | Beef | 2 | .557 | .485 | −13.0 |
| | Pork | 11 | .577 | .545 | −1.5 |

| Method of processing | Kind of meat | Samples | Iron | | |
|---|---|---|---|---|---|
| | | | In raw meat | In dehydrated meat | Gain (+) or loss (−) |
| | | *Number* | *Mg. per 100 gm.* | *Mg. per 100 gm.* | *Percent* |
| Vacuum rotary | Beef | 4 | 5.7 | 9.7 | +70.0 |
| | Pork | 12 | 6.5 | 6.7 | +3.1 |
| Kettle cabinet | Beef | 2 | 7.4 | 8.7 | +18.0 |
| | Pork | 11 | 5.2 | 4.8 | −7.7 |

[1] Dry weight basis.

TABLE 5.—*Changes in nicotinic acid and thiamine content of dehydrated pork during storage*[1]

| Origin of sample | Length of storage | Gain (+) or loss (−) at designated storage temperature | | | | | |
|---|---|---|---|---|---|---|---|
| | | 70° F. | | 110° F. | | 50°-110° F. (alternating) | |
| | | Nicotinic acid | Thiamine | Nicotinic acid | Thiamine | Nicotinic acid | Thiamine |
| | *Weeks* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Commercial firm | 8 | +6.0 | −33.3 | +4.8 | −99.5 | ---- | ---- |
| | 24 | −1.9 | −54.3 | −13.0 | −99.5 | −11.1 | −99.6 |
| | 36 | −5.3 | −64.0 | −10.5 | −99.9 | 0 | −99.9 |
| Beltsville Research Center | 8 | 0 | −27.0 | +5.4 | −81.8 | +4.8 | −64.9 |

[1] Air-packed in container E (described under Packaging).

In the storage experiments, as shown in table 5, thiamine appeared to be unstable at temperatures of 70° F. and above, and there were indications that the same was true after long periods of time even at lower temperatures. At 110° and at temperatures alternating between 50° and 110°, practically all the thiamine was lost after 8 weeks.

Analyses of both fresh and dehydrated meats after cooking, with the cooking liquor included in each case, showed no destruction of nicotinic acid due to cooking. Only about 15-percent loss in riboflavin occurred. The loss in thiamine varied, at times being as high as 60 percent.

### *Significant Results of Vitamin and Mineral Studies*

Dehydration caused relatively small losses of riboflavin and nicotinic acid but those of thiamine were about 50 percent. No important change occurred in the mineral content as a result of dehydration.

## REHYDRATION

There is little doubt that, other factors being equal, the greater the capacity of a sample of dehydrated meat to absorb and hold moisture, the closer is its approach to fresh meat with respect to certain elements of palatability. Involved in this matter is the extent to which the protein of the product has been coagulated (denatured), since it is well known that the water absorption—rehydration—is by the protein tissue and not by the fat. As a phase of the investigation, studies were conducted to throw light on the effects of variations in protein and fat content, size of particle, method of pretreatment, and processing method, on the ability of the finished product to rehydrate.

The procedure developed for determining rehydration consisted essentially in soaking the unground dehydrated meat samples in distilled water, draining, and centrifuging to remove any excess water, under a standard method developed for the purpose. Results were recorded as grams of water retained per 100 grams of dehydrated meat. As an example of results obtained, a group of samples representing one type of cooking prior to cabinet drying gave approximately 50-percent higher rehydration value than another comparable group representing a distinctly different type of cooking.

To show the effect, on rehydration, of a variation in protein or fat content, tests were made on a series of pork samples, dehydrated by the vacuum rotary process. They contained 64.8 to 55.5 percent of protein and 26.5 to 39.4 percent of fat. The corresponding range in rehydration values was 38.5 to 16.6 grams of water per 100 grams of dehydrated meat. In another test, when fat was removed in increasing amounts by suction from a high-fat sample of pork dehydrated by the vacuum rotary method, rehydration values increased correspondingly from 7.4 to 37.3.

That size of particle has an important effect on rehydration was clearly shown. Each of several samples of dehydrated meat was passed through a set of sieves varying in size of mesh. The meat

retained by each sieve was then subjected to rehydration. The values obtained, again expressed as grams of water absorbed per 100 grams of dehydrated meat, varied inversely with the size of the particle. This variation appears to be due to a difference in surface area, since a given weight of product consisting of small particles presents more surface for moisture absorption than the same weight of large particles.

Examination was made of three groups of pork samples described as: (1) Low-fat, high-protein, small particles; (2) low-fat, high-protein, large particles; and (3) high-fat, low-protein, small particles. All were drum cooked and air dried. The respective mean rehydration values were 41.3, 30.9, and 24.1. Statistical analysis indicated that the difference in protein content between the first and third groups of the same particle size had more effect on rehydration capacity than did the difference in particle size between the first and second groups in which the protein content was practically the same.

When an intermediate or high steam pressure was used in the double-drum machine, the two drums being set at least moderately close together (0.10 inch), examination of the meat particles indicated that they were more or less "case hardened," meaning a hardening of the outer surface. It was reasoned that should this be true, the rehydration capacity undoubtedly would be decreased. When a group of pork samples precooked in a kettle for 30 to 45 minutes at 165° to 212° F. was compared with a similar group drum precooked at 70 pounds of steam pressure (corresponding to about 316°), with 0.10-inch separation between drums and 45 seconds per drum revolution, it was found that the former was

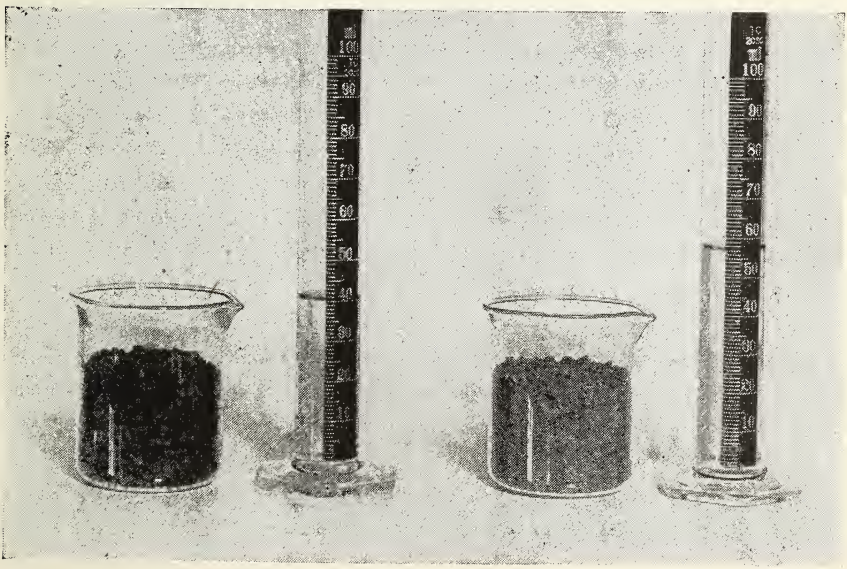

FIGURE 7.—Relative amounts of water absorbed by pork dehydrated by the drum cabinet (left), and by the vacuum rotary (right). Both samples were from the same lot of raw meat.

much superior in capacity to absorb and hold moisture.

Pork dehydrated by the vacuum rotary process gave a mean rehydration value about equal to that obtained from samples of comparable meat dehydrated by the kettle cabinet process. The drum cabinet process resulted in lower rehydration value (fig. 7). In another test in which all of six samples, representing six processes, were obtained from the same lot of raw meat, the vacuum rotary and freezer cabinet processes gave much the highest, and approximately the same, rehydration values.

*Significant Results of Rehydration Studies*

The capacity of dehydrated meat for absorbing water, thereby approaching its fresh condition, was aided by a high protein content, fine grinding, and avoidance of high precooking and dehydrating temperatures.

## PALATABILITY

Palatability tests of numerous samples of meat were made before and after dehydration and after packaging and storage under various conditions, including air pack, nitrogen pack, and vacuum pack. At the beginning of the work, no cooking method was known to be suitable for preparing the dehydrated products for palatability tests. Therefore, the problem was to determine whether precooked dehydrated meat could be tested successfully without further cooking and, if not, to develop a satisfactory technique for further cooking.

After numerous experiments, the testing of palatability of dehydrated meat without further cooking was abandoned. Hence, all scores analyzed in this report represent judgments on fresh cooked meat or on precooked dehydrated meat that was further cooked just prior to testing. With respect to processes, this report deals with pork and beef produced by the vacuum rotary and drum cabinet methods.

### Methods of Cooking and Testing

Whenever feasible, samples from the same lot of meat were tested (1) as fresh meat, (2) immediately after dehydration, and (3) after storage under various conditions. The fresh meat was used as a basis of comparison, for evaluating the dehydrated product.

Of the samples of fresh meat used, a portion of each was broiled for a given length of time and another portion was steamed until tender in a covered pan set in hot water. The broiling method was used to ascertain the character of the developed flavor and the degree of tenderness of the fresh meat. The steaming method modified the fresh-meat flavor as little as possible by cooking and yielded further information on tenderness through the time required to make the meat tender.

Except for some of the drum cabinet samples, cooked in stews with vegetables, the dehydrated-meat samples were cooked unseasoned in distilled water. Judging meat unseasoned permits better detection of the flavors in the meat itself. Different cook-

ing methods were applied, such as over simmering water, over boiling water, or by direct heat, for various periods of time. During the studies a standard method was adopted in which 40 grams of dehydrated meat was cooked in 150 cubic centimeters of distilled water over boiling water for 50 minutes.

Meat prepared as described above was judged by a panel of three to five men and women. The general procedure was as follows:

The meat samples, marked by a code number to conceal their identity from the judges, were served to them, one sample at a time. Except in a few instances when judgments were based on flavor only, the judge scored each sample for appearance, odor, flavor, and texture. He also added an over-all rating of the acceptability, using one of the terms "excellent," "good," "fair," "poor," and "very poor." The corresponding numerical ratings were 5, 4, 3, 2, 1. There were several instances in which the laboratory staff judged that certain meat samples were not suitable to serve the panel; in these cases a palatability rating of very poor was given.

Most of the tests were repeated under different cooking methods. The final palatability scores were obtained by averaging the judges' scores on the various cooking methods. In view of the individual differences in scores among judges and the natural variability in the material, the influence of the factors studied on the palatability of the dehydrated meat showed up more clearly when several scores were averaged than when single scores were compared.

## Palatability as Related to Processing, Storage, and Character of Fresh Meat

When tested immediately after dehydration, meat precooked at the relatively low temperature of 165° F. was somewhat more acceptable than that precooked at 212° in the vacuum rotary process, temperatures being determined at the center of the mass of ground meat. This result was to be expected since temperatures lower than 212° for cooking meat are generally preferred to higher temperatures. On the other hand, the dehydrated meat retained its palatability better during storage when pretreated at the higher temperature. This result is noteworthy in view of the fact that it is assumed that dehydrated meat will be stored before being used.

The temperature to which the meat was subjected in the precooking step of the drum cabinet process increased with increase in steam pressure within the drums. It is not surprising, therefore, that the general trend of the results is similar to that in the vacuum rotary process. The freshly dehydrated meat scored higher when precooked at a steam pressure of 60 to 80 pounds than at 90 to 100 pounds. However, when the dehydrated meat was stored, palatability was better retained by the samples precooked at the higher steam pressure or temperature.

Table 6 indicates relationships, in several instances, between particle size and fat content of the raw meat, on the one hand, and palatability of the dehydrated meat, on the other hand. In the first comparison, involving eight lots of pork containing 10 to 15

percent of fat, the lots consisting of the larger particles scored higher in palatability after storage. The same general trend was true of two other comparable lots of pork. Both these comparisons were of pork dehydrated by the vacuum rotary process. In pork prepared by the drum cabinet process, not enough samples of large particle size were available for a grouping. However, in samples composed of small particles, those of relatively high fat content (9 to 11 percent) scored higher in palatability than those of low fat content (7 percent), both as freshly dehydrated product and as stored product.

Three pairs of beef samples dehydrated by the vacuum rotary process were investigated. The results were in general agreement with those obtained from the corresponding pork samples. As also shown in table 6, after storage at 110° F. the samples of 9-percent fat content and 1.1-inch particle size were somewhat more palatable than those of the same fat content but of only 0.25-inch particle size. The former were also more acceptable than samples of the same particle size but of a lower fat content (4 percent).

TABLE 6.—*Palatability scores of dehydrated meat stored in cans under specified conditions, as affected by particle size and fat content of raw meat*

| Dehydration process and kind of meat | Lots[1] | Particle size (diam. of holes in grinder plate) | Fat content of raw meat | Average palatability scores[2] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Before dehydration | After dehydration— | | | | | |
| | | | | | Before storage | After storage at 110° F. | | | | |
| | | | | | | Air pack | Nitrogen pack | | Vacuum pack | |
| | | | | | | 100 days | 100 days | 200 days | 100 days | 200 days |
| Vacuum rotary: | *Number* | *Inches* | *Percent* | | | | | | | |
| Pork | 4 | 0.25 | 10-14 | 3.7 | 3.3 | 2.0 | 2.0 | ---- | 2.2 | ---- |
| | 4 | 1.1 | 10-15 | 3.9 | 3.1 | 2.5 | 2.5 | ---- | 2.6 | ---- |
| | 1 | .25 | 10 | 3.8 | 3.5 | 2.0 | 1.2 | ---- | 2.2 | ---- |
| | 1 | 1.1 | 12 | 3.9 | 2.5 | 3.0 | 2.8 | ---- | 2.7 | ---- |
| Beef | 2 | 1.1 | 4 | 3.5 | 2.7 | 1.8 | 1.6 | ---- | 1.7 | ---- |
| | 2 | .25 | 9 | 3.3 | 3.1 | 2.2 | 2.1 | ---- | 2.3 | ---- |
| | 2 | 1.1 | 9 | 3.2 | 2.5 | 2.7 | 2.2 | ---- | 2.7 | ---- |
| Drum cabinet: | | | | | | | | | | |
| Pork | 6 | .25 | 7 | 3.8 | 2.7 | ---<br>1.5 | ----<br>1.9 | ----<br>1.7 | [3]2.3<br>2.3 | [3]2.7<br>1.8 |
| | 11 | .25 | 9-11 | 3.5 | 3.3 | ---<br>1.8 | ----<br>2.2 | ----<br>2.5 | [3]2.8<br>2.4 | [3]2.9<br>2.5 |

[1] Limited facilities made it impossible to test each lot of meat under all storage conditions; 61 percent of the average palatability scores are based on more than 50 percent of the tested lots of meat.

[2] Maximum score, 5; minimum score, 1. Factors considered by the judges were appearance, odor, flavor, and texture. Palatability scores are based on ratings of all judges and all cooking methods.

[3] Storage at approximately 35° F.

In further comparisons of the vacuum rotary and drum cabinet methods in addition to the data tabulated, study was made of all comparable samples after storage in cans. For pork stored at approximately 35° and 110° F., the palatability scores of the vacuum rotary products were 3.0 and 2.4, respectively, whereas the corresponding scores for drum cabinet products were 2.7 and 2.0.

Table 7 shows the influence of three different types of pack—air, nitrogen, and vacuum—on the palatability of pork and beef dehydrated by two different methods and stored at 35° and 110° F.

TABLE 7.—*Palatability scores[1] of dehydrated beef and pork processed by 2 different methods, as affected by storage under specified conditions*

| Dehydration process, temperature of storage, and type of pack | Average score for specified periods of storage[2] | | | |
|---|---|---|---|---|
| | 0 day | 30 days | 100 days | 200 days |
| Vacuum rotary process: | | | | |
| Beef | 2.7 (11) | | | |
| 35° F. | | | | |
| Air | | ---- | 3.0 (1) | ---- |
| Nitrogen | | ---- | ---- | ---- |
| Vacuum | | ---- | 2.9 (9) | 2.5 (6) |
| 110° F. | | | | |
| Air | | 2.6 (4) | 2.1 (8) | 1.7 (4) |
| Nitrogen | | 2.8 (4) | 2.0 (9) | 1.8 (5) |
| Vacuum | | 2.9 (4) | 2.1 (10) | 1.9 (7) |
| Pork | 3.2 (18) | | | |
| 35° F. | | | | |
| Air | | ---- | 3.0 (1) | 3.0 (3) |
| Nitrogen | | ---- | ---- | ---- |
| Vacuum | | ---- | 3.0 (13) | 2.9 (6) |
| 110° F. | | | | |
| Air | | 3.0 (10) | 2.3 (14) | 1.6 (9) |
| Nitrogen | | 3.0 (10) | 2.3 (14) | 1.8 (7) |
| Vacuum | | 3.2 (10) | 2.4 (14) | 2.0 (6) |
| Drum cabinet process: | | | | |
| Pork | 3.1 (43) | | | |
| 35° F. | | | | |
| Air | | ---- | 2.7 (21) | 2.5 (6) |
| Nitrogen | | ---- | ---- | ---- |
| Vacuum | | ---- | 2.7 (17) | 2.9 (8) |
| 110° F. | | | | |
| Air | | 1.7 (1) | 1.4 (36) | 1.7 (19) |
| Nitrogen | | 2.2 (3) | 2.1 (18) | 2.2 (13) |
| Vacuum | | 2.2 (3) | 2.3 (18) | 2.3 (12) |

[1] Maximum score, 5.0; minimum score, 1.0. Factors considered by the judges were appearance, odor, flavor, and texture. Palatability scores are based on ratings of all judges and all cooking methods.

[2] Figures in parentheses indicate number of samples from different lots of meat.

for 30, 100, and 200 days. Scores of the same dehydrated meat, before storage, are included for comparison.

The product packed in vacuum maintained palatability slightly better than that packed in nitrogen, and the latter was, in general, slightly better than the meat packed in air. Samples processed by the drum cabinet method, however, showed more difference in favor of the nitrogen pack over the air pack than did samples processed by the vacuum rotary method.

Table 7 shows also that at a storage temperature of 110° the palatability scores of pork and beef dehydrated by the vacuum rotary process decreased as the storage time increased from 30 to 200 days. The palatability scores of pork from the drum cabinet process showed no consistent trend as the storage period increased from 30 to 200 days, but they decreased to a much greater extent during the first 30 days of storage than did the scores of products dehydrated by the vacuum rotary method.

Of the two storage temperatures, 35° and 110° F., the lower was the better; the higher temperature resulted in the greater deterioration in palatability.

To compare the effects of the vacuum rotary and drum cabinet methods on the palatability of the processed meat, all available data on pairs of fresh and freshly dehydrated pork samples from the same lots of meat were studied. The average acceptability of the fresh meat was practically the same for both processes (3.7 for vacuum rotary and 3.6 for drum cabinet). The decrease in

palatability due to processing averaged 0.7 for the vacuum rotary and 1.0 for the drum cabinet process.

## Palatability as Related to Type of Container and Time and Temperature of Storage

A further test was made of the combined influence of the type of container and the time and temperature of storage on the palatability of dehydrated pork. The product used in this test was obtained from a commercial firm. It was of uniform quality except that a portion contained added salt, the sodium chloride content of the product being 3.23 percent. Five paper and metal-foil containers, as well as tin-plate cans, were used. Four of the former, identified as A, B, C, and E, are described under Packaging; the fifth, identified as F, was made from a heavy 3-ply, laminated material with the bags stitched along the sides and at the top for closure and then dipped in wax.

The following nine methods of packing were used in the present study: No. 2 tin-plate can, vacuum pack; container E; salt added; No. 2 tin-plate can, nitrogen pack; container E; No. 2 tin-plate, air pack; container C; container B; container A; and container F.

Samples packed by each of the nine methods were stored at 0°, 70°, 110°, and at temperatures alternating between 50° and 110° F., on a 24-hour cycle. Storage periods were 8, 16, 24, and 36 weeks.

On their removal from storage, the samples were prepared for the palatability test by cooking 40 grams of dried meat in 150 cubic centimeters of water over boiling water for 50 minutes. They were then tested by a panel of three judges who used the following rate scale: Excellent, 5; good, 4; fair, 3; poor, 2; very poor, 1.

Beginning with a relatively low initial palatability score of 3.2 immediately after dehydration, the meat packed in tin cans gave average palatability scores, for all temperatures and time of storage, of 2.3, 2.1, and 1.9 for vacuum, nitrogen, and air packs, respectively. Thus, the vacuum pack was somewhat preferable to the nitrogen pack, and the air pack gave poorest results. In container E (air pack) the average palatability ratings were 2.2 and 2.1 for the same meat with and without added salt. Addition of salt improved, to a small extent, the palatability of dehydrated meat packed in container E. The ratings of samples in the other containers were lower, ranging from 1.8 in container C to 1.7, 1.6, and 1.4 in containers B, A, and F, respectively.

As a basis for studying the influence of storage temperatures on the palatability of the dehydrated meat, the scores of the product packed in all containers and stored for all periods were averaged. The average score for meat held at 0° F. was 2.5 as compared with 1.9, 1.7, and 1.6 for storage temperatures of 70° and 110° and an alternating storage temperature of 50°-110°, respectively. The rates of decrease in palatability score of meat at storage temperature of 110° and at the alternating temperature were similar and were somewhat more rapid than at 70°. The rate of decrease at 0° was relatively slow. The average palatability score for de-

hydrated meat representing all containers and temperatures decreased from 3.2, before storage, to 2.3, 1.8, 1.7, and 1.8 after storage, for 8, 16, 24, and 36 weeks, respectively.

## Palatability as Affected by Utilization in Stews

Although it is desirable that dehydrated meat of the usual precooked type be suitable for use in as many different ways as fresh meat, precooking as a step in dehydration naturally limits its use to dishes that can be prepared from cooked meat. The studies reported here dealt with such dehydrated meat prepared in the form of stews. The purpose was to investigate the adaptability of dehydrated meat to this use and the extent to which its palatability might be affected.

Unused portions of dehydrated pork, beef, and mutton subjected to palatability tests were held at 0° F. until a sufficient number of samples of various acceptability scores were available. The pork samples (table 8) represented four categories, namely, very poor,

TABLE 8.—*Palatability scores* [1] *of dehydrated pork, beef, and mutton of various qualities as affected by 3 different cooking methods*

| Method of cooking | Pork sample No.— | | | | Beef sample No.— | | Mutton sample No.— | |
|---|---|---|---|---|---|---|---|---|
| | 1 (very poor) | 2 (poor) | 3 (fair) | 4 (good) | 1 (poor) | 2 (fair) | 1 (poor) | 2 (fair) |
| In water with added salt | 1.0 | 1.9 | 2.1 | 2.8 | 1.7 | 2.4 | 1.7 | 2.5 |
| As in first method, with vegetables and flour thickening added | 1.0 | 2.5 | 2.5 | 3.2 | 2.3 | 2.5 | 2.0 | 3.0 |
| As in second method, with increased proportions of carrots and onions; pepper added | 1.0 | 2.8 | 3.0 | 3.5 | 2.5 | 2.7 | 3.0 | 3.2 |

[1] Maximum score, 5; minimum score, 1.

poor, fair, and good. The two samples of beef and also those of mutton were classified as poor and fair.

The meat was rehydrated by a method suggested by Sharp[5], in which the liquid (6-percent salt solution) was added to the meat in a proportion depending on the fat and moisture content of the meat. This mixture was then placed in the upper part of a double boiler, covered, and cooked over boiling water for 1 hour. This procedure corresponded to the first method shown in table 8. This reconstituted meat was judged as such and also after the addition of other ingredients as indicated in the last two methods.

The stews were served to the judges immediately, and all tasting was completed within one-half hour. The same judges and score sheet previously used in the palatability studies of rehydrated meat were used for scoring the stews.

Stews made from meat judged "very poor" were no more palatable than the original dehydrated meat. However, the palatability scores of samples of higher original ratings increased with increasing additions of vegetables and seasonings.

The general comment from the judges was that there was not so pronounced a meat flavor in the stews as in similar stews made with fresh meat. Moreover, they missed the large pieces of meat

[5] J. G. Sharp, Low Temperature Research Station, Cambridge University, Cambridge, England; personal communication.

characteristic of a fresh-meat stew. It would seem that this objection could be overcome, at least in part, through the use of meat dehydrated in larger particles.

### *Significant Results of Palatability Studies*

In both the vacuum rotary and drum cabinet processes, precooking at a relatively low temperature resulted in a more palatable product than at a relatively high temperature, when the meat was reconstituted, without seasoning, and tested immediately after dehydration. Palatability was retained somewhat better in storage, however, when precooking was done at the higher temperatures. Larger particle size and higher fat content appeared to contribute to palatability. When dehydrated beef and pork were packed in tin cans and stored at 35° and 110° F., there was greater deterioration in palatability at the latter temperature. In a test of types of containers and methods of packing, dehydrated pork vacuum-packed in tin cans deteriorated slightly less in palatability than in any other instance. The meat flavor in stews made with dehydrated meat was not so pronounced as in those made with fresh meat. Palatability scores for samples of dehydrated meat with relatively high ratings increased with increasing additions of vegetables and seasonings in stews.

## FURTHER COMPARISON OF PROCESSES

Comparison of processes was a general theme of the research. For various reasons, however, it was not possible at one time to make a comprehensive, comparative study of all processes involved in the investigations, with the use of strictly uniform raw material and a consideration of all quality factors of the product. Nevertheless, to throw more light on the value of different processes, one relatively large lot of pork, containing about 9.5 percent of fat on the raw basis, was divided into six parts of uniform composition. Each part was dehydrated by a different method. The processes chosen for the experiment were those that had shown good possibilities, and the conditions of processing employed in each case were those which previous experience in the work indicated to be most practicable. The samples were prepared as follows:

*Sample No. 765, vacuum rotary process.* The fresh pork was ground into 0.25-inch particles and cooked for 70 minutes at 150° F. in the vacuum rotary machine A while air was being blown over the meat. A vacuum of 29 inches was applied, and the meat was dried at 108°-140° in 4 hours 40 minutes to a moisture content of 5.73 percent.

*Sample No. 766, air rotary process A.* The meat was ground into 0.25-inch particles, cooked for 30 minutes at 212° F. in the steam-jacketed kettle, and then reground into 0.125-inch particles. It was then passed through the air rotary (steam tube) drier A at a feeding rate of about 0.16 pound every 2 minutes. The tubes were maintained at 60 pounds of steam pressure, and the cylinder made one revolution in 25 seconds. The meat was dried to 10.83 percent of moisture in 2.5 hours.

*Sample No. 767, air flotation process.* The meat was ground into 0.25-inch particles and precooked on the double-drum drier. The drums were spaced one-sixteenth inch apart, made one revolution in 45 seconds, and were maintained at 70 pounds of steam pressure. The meat was dried in the air flotation drier at 170° F., with 31-percent relative humidity, in 2.5 hours to a moisture content of 9.97 percent.

*Sample No. 768, kettle cabinet process.* The meat was ground into 0.25-inch particles and precooked in the steam-jacketed kettle at 212° F. for 30 minutes. The precooked meat was dried in cabinet drier A at 180° and 31-percent relative humidity for 1.5 hours, and at 160° and 31-percent relative humidity for 2 hours. The final moisture content was 8.91 percent.

*Sample No. 769, kettle cabinet process (with antioxidant added to the meat).* The meat was ground into 0.25-inch particles and cooked in the steam-jacketed kettle for 30 minutes at 212° F. During the last 10 minutes of precooking, the antioxidant (gum guaiac) was sprayed onto the rapidly moving meat, the concentration on the fresh-meat basis being 0.03 percent. The meat was dried in the same manner as was sample No. 768.

*Sample No. 770, freezing cabinet process.* The raw meat was transferred to a refrigerator at 0° F. and frozen overnight. The frozen meat was ground into 0.25-inch particles, spread evenly on trays, and dried in the cabinet drier B, with through circulation of air at 120° for 4 hours 15 minutes. The moisture content was 3.76 percent.

The characteristics of the various samples, reflecting the differences in processing methods, are shown in tables 9 and 10. Table 9 gives information on dehydrated meats immediately after dehydration, whereas table 10 contains data for the products exposed to relatively high temperatures in an atmosphere of oxygen for the purpose of obtaining a more rapid response than would result from exposure to air.

Table 9 indicates no serious fat loss except in sample No. 767, prepared by the air flotation process. This sample lost more than 18 percent of its original fat. This is an important loss since the original meat was of relatively low fat content. In flavor, sample No. 770 was markedly superior to any of the others, No. 766 being lowest.

As a measure of fat deterioration, the free fat acid percentages for the freshly dehydrated samples indicated a fairly normal condition in all cases. On subjection to higher temperatures, however, No. 770 increased greatly in free fat acid content. This may have been due to enzymic activity, since the sample was processed at temperatures below those known to inactivate enzymes.

All samples had little or no protein break-down, as indicated by ammonia nitrogen determinations. All samples had fair rehydration capacity, but Nos. 765 and 770 were clearly superior to the others in this respect.

With respect to vitamin content, the nicotinic acid of all the samples showed negligible changes from that present in the fresh meat. The riboflavin content, although noticeably reduced, was

TABLE 9.—*Effect of different dehydration processes on flavor, certain chemical properties, and vitamin content of pork from the same lot of raw meat, immediately after dehydration*

| Sample No. | Dehydration process | Flavor ratings | | Loss of fat in processing (as percentage of weight of meat) | Free fat acid in extracted fat | Ammonia nitrogen (protein basis) | Rehydration (water retained per 100 grams of dehydrated meat) | Vitamins per 100 grams of dry weight | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Average score[1] | Description | | | | | Nicotinic acid | Riboflavin | Thiamine |
| | | | | *Percent* | *Percent* | *Percent* | *Grams* | *Milligrams* | *Milligrams* | *Milligrams* |
| --- | None (fresh meat) | ---- | ---- | ---- | ---- | ---- | ---- | 10.3 | 2.82 | 2.52 |
| 765 | Vacuum rotary | 2.5 | Good | 0.69 | 0.98 | 0.031 | 56.3 | 12.3 | 1.83 | 2.46 |
| 766 | Air rotary | 1.9 | Fair | .99 | 1.20 | .035 | 41.0 | 11.0 | 1.86 | 2.00 |
| 767 | Air flotation | 2.6 | Good | 5.32 | 1.29 | .025 | 39.8 | 11.3 | 2.10 | 1.80 |
| 768 | Kettle cabinet | 2.4 | Fair | .79 | .94 | .037 | 44.2 | 9.8 | 1.76 | 1.67 |
| 769 | Kettle cabinet (antioxidant added) | 2.2 | do | 1.43 | .88 | .039 | 43.8 | 9.8 | 1.93 | 1.95 |
| 770 | Freezing cabinet | 3.6 | Excellent | .17 | 1.53 | .021 | 60.0 | 11.5 | 1.60 | 2.50 |

[1] Based on a scale of: 3.5 or more, excellent; 2.5 to 3.5, good; 1.5 to 2.5, fair; and 1.5 or less, poor.

approximately as well retained in one process as in the others. The thiamine values showed excellent retention in sample No. 770 (dried at 120° F.) and in No. 765 (prepared in vacuum). No. 766, although subjected to high temperature, was exposed to little air and showed good thiamine retention. No. 769, which was exposed to large volumes of air and to high temperature but contained an antioxidant (gum guaiac 0.03 percent), also showed good thiamine retention. Nos. 767 and 768, exposed to large volumes of air and to comparatively high temperatures, showed poorest thiamine retention.

TABLE 10.—*Comparisons of stability and other properties of pork dehydrated by different processes, sealed in tin cans in the presence of oxygen, and then subjected to relatively high temperatures*

| Sample No. | Dehydration process | Stability in oxygen at 158° F.[1] | Stability in oxygen at 110° F. | | |
|---|---|---|---|---|---|
| | | | Time elapsed before rancidity was first detected | Oxygen absorption per gram of meat when rancidity was first detected | Free fat acid (based on extracted fat) |
| | | *Hours* | *Hours* | *Milligrams* | *Percent* |
| 765 | Vacuum rotary | 87 | 325 | 1.86 | 1.91 |
| 766 | Air rotary | 37 | [2]0 | ---- | 1.19 |
| 767 | Air flotation | 51 | 72 | .65 | .85 |
| 768 | Kettle cabinet | 69 | 72 | .51 | 1.03 |
| 769 | Kettle cabinet (antioxidant added) | 100 | 710 | 2.00 | .86 |
| 770 | Freezing cabinet | 165 | [3]902 | >1.54 | 12.96 |

[1] Time required, owing to absorption of oxygen by the meat, for decreased pressure in a closed system containing meat sample and oxygen to lower a column of mercury 100 mm.
[2] Rancid at beginning.
[3] Not rancid at this stage.
> Signifies more than.

As shown in table 10, which presents comparisons of the same samples after their exposure to oxygen, the stability values obtained at 158° and 110° F. corroborate each other well. It is remarkable that although No. 770 indicated high enzyme activity from its high free fat acid content on storage, it was extremely stable. The sample treated with antioxidant (No. 769) showed the value of the treatment. The vacuum rotary process sample (No. 765) was superior in stability to any untreated (no added antioxidant) air-dried sample subjected to high temperatures.

The freezing cabinet process resulted in a product (No. 770) superior to the others in stability, flavor, rehydration capacity, and even in thiamine retention, although with respect to the last two factors the differences between this sample and No. 765, which was prepared by the vacuum rotary process, were very small. However, even at the low moisture content of 3.8 percent, enzyme activity was indicated by the high rate of action on the fat.

Of the methods compared, the vacuum rotary process appeared to be the most promising for prompt practical application. It produced meat of good stability, flavor, rehydration capacity, and vitamin retention. Dehydrated pork processed by the kettle cabinet method with the addition of antioxidant was of fair flavor and of good stability and retained the vitamin content fairly well. The kettle cabinet product without antioxidant and the air flotation product were fair and good, respectively, in flavor and were

of only moderate stability. The former product was the lowest of all samples in thiamine retention, and the latter was next.

Dehydrated pork least satisfactory in flavor and stability and low in rehydration capacity was produced by the air rotary process. However, the retention of thiamine was about average.

### *Significant Results of Comparisons*

These results indicate that the quality, including the stability, of dehydrated meat depends largely on both the quantity and temperature of the drying air. Low-temperature dehydration, even with the use of a large volume of air, resulted in a product that in general was highly satisfactory, keeping quality being the principal problem. At a higher temperature, with a minimum amount of air, satisfactory dehydrated meat was produced by the vacuum rotary process. With the still higher temperatures and large quantities of air used in the kettle cabinet and air flotation processes, the products were of lower quality in general.

## SPECIFICATIONS FOR COMMERCIAL PRODUCTION

Late in the spring of 1942 it became apparent that there would soon be need of specifications which could be used in connection with the commercial production of dehydrated beef, primarily for lend-lease purposes. Although their studies were only well begun, the Department research workers were asked to furnish all pertinent available information and to participate in formulating such specifications. In collaboration with representatives of the Department's Food Distribution Administration and the meat industry and others, and utilizing the best data and judgment that could be brought together, they drafted the desired requirements for commercial dehydrated beef. The essential points relating to the character of the raw material, processing procedure, characteristics of the finished product, packaging, and inspection, were as follows:

Dehydrated beef shall consist of beef derived from the entire carcasses of cattle of U. S. Canner grade or better. Meat from bulls shall be excluded. Closely trimmed beef cheek meat and beef head meat may be included up to 3 percent of the total meat used. The meat shall be reasonably free from blood clots, bruises, stringy fibrous tissue, tendons, and sections of large blood vessels.

Fat content of the finished product shall not exceed 30 percent.

Salt may be added to the meat to the extent that the finished product shall average not more than 3½ percent of sodium chloride.

The meat shall be precooked a minimum of 30 minutes at not less than 165° F. internal temperature.

After precooking, the meat shall be promptly dried until the moisture content does not exceed 10 percent in any particle of the dehydrated meat product when placed in the container.

The dehydrated beef shall be packed as tightly as possible into rectangular or round tin cans, hermetically sealed with or without vacuum, and shall be packed into containers meeting the requirements of Federal specifications for canned meat for export.

The processor of the dehydrated beef was to give assurance that:

In all respects it shall be equal to or better than the sample numbers _____, _____, _____, submitted with this offer, and shall have

been prepared and packaged under strictly sanitary conditions and in accordance with good commercial practice.

Inspection will be made at our plant prior to shipment. The meat shall be processed in establishments where the inspection services of the Bureau of Animal Industry are maintained.

On July 1, 1942, the Agricultural Marketing Administration of the Department announced that purchases of granular, flaked, or powdered dehydrated beef were contemplated and that offers for the sale of the product might be submitted. However, by the time this announcement was made the realization had begun to grow that, in the light of prospective supplies of raw material, the emphasis in this country should be placed on dehydrated pork instead of dehydrated beef. As a consequence, only a relatively small quantity of the beef was produced and purchased.

Steps were therefore begun to develop suitable specifications for dehydrated pork. Again the research workers in the Department were asked to take much of the responsibility. As in the previous instance, the requirements for this product were developed in collaboration with others. The experience obtained in the work relating to the beef specifications and the further progress that had been made on the research program aided in formulating the specifications for dehydrated pork. The latter were essentially as follows:

Dehydrated pork, to be processed in 1-pound cans, shall be prepared from boneless pork reasonably free from trimmable fat, blood clots, glands, bruises, stringy fibrous tissues, tendons, and sections of large blood vessels. Shank meat may be used as produced in proportion to the quantity of hams or shoulders included. Head meat, cheek meat, and pork with dark flesh or coarse muscle fiber shall not be included.

The fat content of the finished product shall not exceed 40 percent. Salt shall not be added to the meat.

The meat shall be precooked a minimum of 30 minutes at not less than 165° F., based on internal temperature.

After precooking, the meat is to be hashed through the ⅛-inch plate, or a larger one, and promptly dried until the moisture content of the dehydrated meat does not exceed an average of 10 percent when placed in the container. The free fat and meat juices that were released from the pork during the precooking operation may be added to the dehydrated pork, provided the moisture and fat contents of the finished dehydrated pork do not exceed the percentages as listed above.

The dehydrated pork shall be packed into rectangular or round cans at not less than 45 pounds per cubic foot of internal container space. The cans shall be hermetically sealed under vacuum.

The product shall be equal to or better than the samples which shall be submitted with each offer for dehydrated pork.

Whenever it is impossible to obtain cans made entirely of hot-dipped tin-plate 1.25 coating, it will be satisfactory to use electrolytic tin-plate or Bonderized black plate.

All animals shall be slaughtered and all meat food products shall be prepared in establishments wherein the inspection service of the Bureau of Animal Industry, United States Department of Agriculture, is maintained, and shall be so identified. The commodity shall be inspected and its weighing shall be supervised by the Market News and Grading Division or by a person or agency designated by and under the supervision of that administration, after the date of acceptance of the offer and prior to the passage of title to the commodity to the vendee. Such inspection will be at the expense of the FSCC unless otherwise specified in the invitations for offers.

FSCC may, at its option, require chemical analysis of meat food products submitted for delivery.

Any chemical analysis required in testing the commodity or product

shall be made in accordance with the methods of the Association of Official Agricultural Chemists in effect on the date of invitation for offers. Such analysis will be at the expense of the FSCC, unless otherwise specified in the invitation for offers.

On November 7, 1942, the Agricultural Marketing Administration amended Schedule FSC-10, Meat Products Purchase Specifications, to include the dehydrated-pork specifications that had been drafted. Commercial production on a conservative scale was begun almost immediately. There was a rapid increase in production in the months that followed.

## SUMMARY AND CONCLUSIONS

In response to lend-lease and military needs for meat of concentrated nutritive value that can be shipped without refrigeration, the Department, early in 1942, engaged in experimental work on the dehydration of beef, pork, lamb, and mutton. The studies were conducted by an interbureau committee of research workers and technicians, principally at the Beltsville Research Center, Beltsville, Md.; some tests were made in Chicago, Ill.

Besides dealing primarily with processes of dehydration, the investigation included studies of packaging, storage, chemical and bacteriological changes, compressibility, rehydration, and the nutritive value and palatability of the products.

Eight methods of dehydration, embodying mechanical features that had proved to be successful with other products, were tested. Special attention was given to adaptations that would make the methods most suitable for meat. The investigators also designed new equipment. The experimental work involved many combinations of equipment, conditions, and procedures.

Grinding to particles of small size and precooking the meat were found to hasten the drying process and improve the keeping quality of the dehydrated product. Grinding after cooking resulted in more rapid drying than grinding before cooking.

On the basis of boned, trimmed, fresh meat, dehydration saves approximately 60 to 70 percent in weight. Reduction in volume, when the dehydrated product is properly compressed, is about 65 to 73 percent.

Of the various processes studied, the vacuum rotary gave indications of combining the most good points. It derives the name from the vacuum principle, used to accomplish the drying in a minimum of air, and from rotary agitation of the meat in a steam-jacketed cylinder. Meat processed by this method had good rehydration capacity, thiamine retention, palatability, and keeping quality, and had other desirable characteristics. The vacuum rotary process, moreover, is simple, combining both precooking and drying in one machine. However, other processes such as the kettle air rotary, the kettle cabinet (which may be considered as representing also the kettle tunnel process), the drum air flotation, and the freezing cabinet process excelled with respect to rate of drying, continuity of operation, palatability of freshly dehydrated product, or otherwise.

Control over processing temperatures and the oxidizing influence

of air was found to be an important aid to successful dehydration.

Dehydrated raw meat, as removed from the drier, appeared to be generally a better product than dehydrated cooked meat but presented a problem in keeping quality requiring further study.

High stability in dehydrated meat, signifying resistance to the development of rancidity, is desirable for three principal reasons: to insure flavor, vitamin content, and longer storage life.

The experimental data indicate that dehydrated meat that is rated high in palatability by a panel of well-trained judges will rate well in stability. A stability test adds to the value of a palatability test and vice versa.

Tests on oxidation and rancidity showed the importance of using, for dehydration, fresh meat that had not been aged. Meat may be fully acceptable for table use and yet be unsuitable for dehydration because of previous action by enzymes or exposure to oxidation by air.

Conditions of processing, packaging, and storing that reduce exposure to air are helpful in obtaining good keeping quality.

The use of small quantities of gum guaiac as an antioxidant improved the keeping quality of dehydrated meat.

Studies of packaging and storage showed that metal cans were the best containers for dehydrated meats and kept them in satisfactory condition for long periods. Besides affording good protection against rough handling and contamination, such containers exclude air and otherwise preserve the palatability of the meat better than others, especially at nonrefrigerating temperatures.

The most satisfactory substitute for cans was the envelope-type, lead-foil bag. Some paper and other nonmetallic containers, although fairly satisfactory under favorable storage conditions, failed when exposed to high humidity and frequent temperature changes.

Dehydrated meats canned by the vacuum pack process retained their palatability slightly better than those canned in an atmosphere of nitrogen. Nitrogen-pack products, in turn, were slightly better than air-pack meat.

Low storage temperatures aided in retaining palatability of canned dehydrated meats, the ratings being based on appearance, odor, flavor, and texture.

Package requirements for meat of high stability need not be so stringent as for meat of low stability.

Compressing dehydrated meat makes it more compact and, by forcing out air, reduces oxidation and contributes to the prevention of rancidity. Compressing at a moderately high temperature prior to packaging is a promising way to remove excess fat.

When meat in fresh condition is properly dehydrated to a moisture content of 10 percent or less and packed in hermetically sealed metal cans, it is a safe food from the bacteriological point of view. Under conditions unfavorable to the growth of molds in dehydrated meat there is slight opportunity for bacteria to develop, but reconstituted meats, unless refrigerated, should be eaten promptly, since they are a good medium for the development of bacteria. Thorough cooking of reconstituted meats is desirable.

Several processes of dehydration provide opportunities for controlling the proportions of protein, fat, and ash, as well as of moisture, in the resulting products. Any step resulting in decrease in fat content is generally accompanied with an increase in protein and ash, and vice versa.

The capacity of dehydrated meat to absorb and hold moisture to a degree approaching its original condition is aided by a high protein content, minimum coagulation (denaturation) of the protein in the processing, and fine grinding. To insure meat of good rehydration quality, the dehydration process should be one that will not harden the surfaces of the meat particles.

The protein of dehydrated pork, beef, and mutton, as determined by rat-feeding tests, was of relatively high growth-promoting value and digestibility. Differences among samples of protein studied were traced principally to the amount of connective tissue in the raw meat, the temperature of dehydration, and the period of exposure to that temperature. Conditions favorable to a high nutritive value were a small proportion of connective tissue and rapid dehydration at the lowest practicable temperature.

The content of vitamins in dehydrated meat varied widely. Thiamine content was most affected by the dehydration process. Losses in riboflavin and nicotinic acid were relatively small. The inclusion of antioxidants during processing resulted in better retention of the vitamins. Thiamine in the dehydrated product was greatly affected by storage, the loss being nearly 100 percent after storage for 8 weeks at 110° F.

Tests of the palatability of meat reconstituted, without seasoning, immediately after dehydration showed that a precooking temperature of 165° F. gave a more acceptable product than precooking at 212°; but the meat precooked at the higher temperature retained its palatability somewhat better in storage.

The flavor of dehydrated meat was not so pronounced as that of fresh meat. Preparing dehydrated meat of good quality in the form of a stew with vegetables and seasonings made it more appetizing.

The investigators in the meat dehydration project collaborated with Federal purchasing officials and representatives of the meat industry in preparing specifications for dehydrated beef and pork and in other ways aided in the commercial application of the research findings.

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